

Sky & Telescope Digital Extra

MAY

JUNE

JULY

AUGUST

WEB EXTRAS

SEPT. 2012 ISSUE

- Solar System Storms
- Meteor Shower Maps
- Vesta Close-ups
- September Occultations

Monthly Audio Sky Tour

THIS WEEK'S

Sky at a Glance



Observing Highlights

Photo Gallery



Image by
Marian Lucian Achim

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New Moon Globe



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Pluto, and Charon
- ▶ Sept. 3 – 9
Lyra, the
celestial Lyre
- ▶ Sept. 10 – 16
The Milky Way's
Great Rift
- ▶ Sept. 17 – 23
Close encounter
with Uranus
- ▶ Sept. 24 – 30
Draco,
the Dragon

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SKY & TELESCOPE

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SEPTEMBER 2012

Extreme Weather

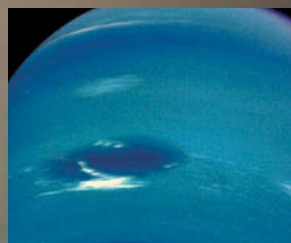
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Tonight p. 50

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Thirty Years—Fabian Neyer

"My first steps into astrophotography were in 2002. I moved on to a full format CCD camera for deeper images. Switching from DSLR to CCD, the limiting factor became my telescope. Up to this point I used a (4"ED) refractor which had good performance using a Bayer matrix and/or large pixel detector. The problem now was insufficient color correction — a smeared blue channel.

In 2011 I finally bought my Tele Vue NP101is APO refractor. It's focal length and relatively fast speed (f/5.4) are perfect for many wide-field objects and the color correction of this nice piece of equipment turned out to be superb! Even the green and red filtered images tend to be sharper than my other refractor and these are already very sharp. The focuser also allows more light to reach the corners, especially using full format or larger detectors. The bottom line here is less vignetting. Another aspect I liked is the unique high-precision, automated focusing system upgrade with some unique features not found elsewhere."

— F.N. Switzerland

"Heart and Soul" image taken with Tele Vue NP101is and SBIG STL11000 CCD camera by Fabian Neyer. See full frame image and details at TeleVue.com



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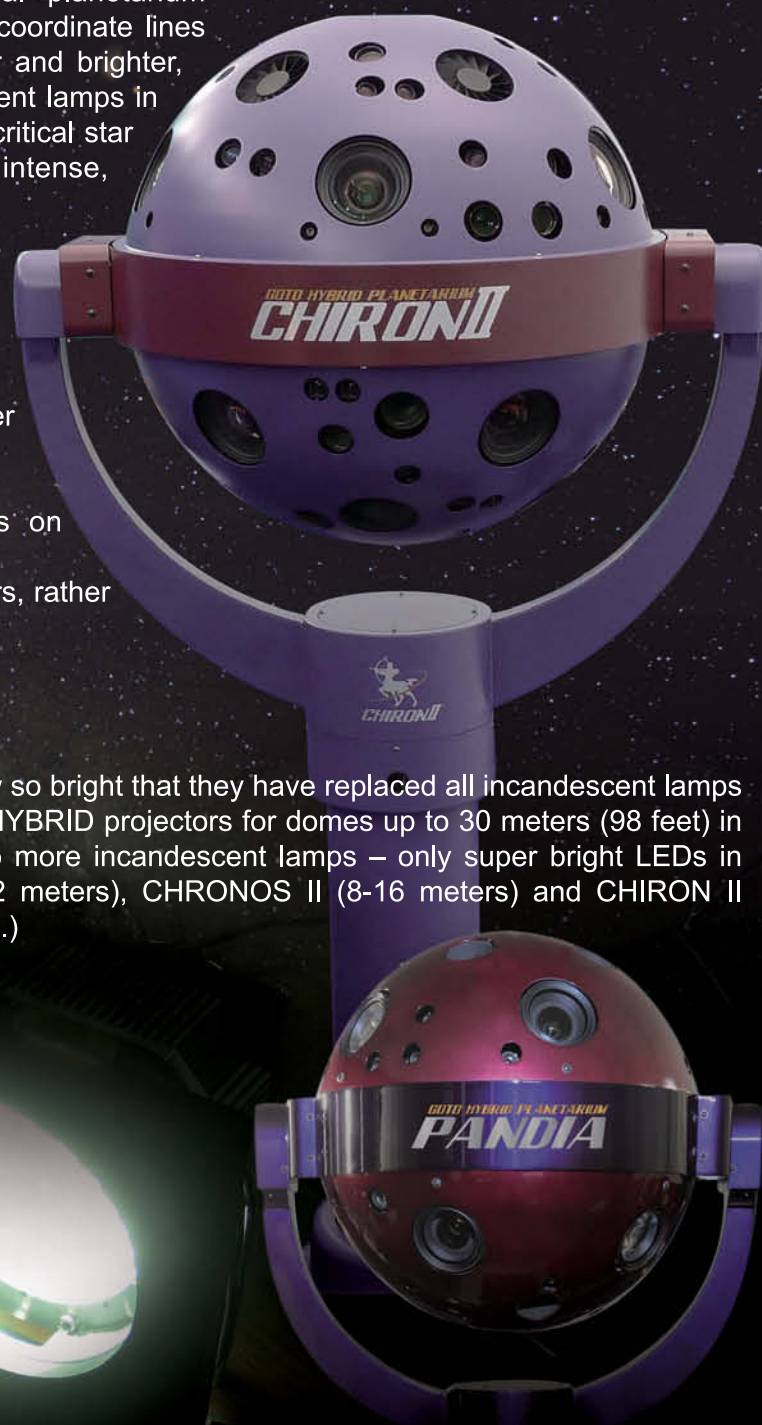
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Great White
Spot expanded to
encircle the
planet like a
stormy snake.

NASA / JPL-CALTECH / SSI

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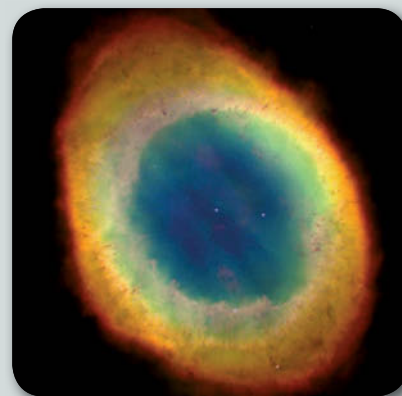


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A Great Transit Experience



Members of the S&T tour group observe the June transit of Venus moments before fourth contact from a beach in Waikoloa, Hawaii.

S&T: ROBERT NAEYE

Wow, the S&T Transit of Venus trip to the Big Island of Hawaii was a fantastic experience. Our tour group enjoyed beautiful views of the transit, especially during the critical periods of ingress and egress. Everyone felt exhilaration after having observed one of nature's rarest spectacles under clear Hawaiian skies and comfortable temperatures.

Our group consisted of about 120 people, many of whom were S&T subscribers or their spouses. We had folks from all over the U.S. and from Australia, Canada, Colombia, Hong Kong, Mexico, and the U.K. As usual on such trips, the participants had an eclectic range of interests and backgrounds, which made for a lot of interesting conversations.

On transit morning, vans transported some of the people in our group to the 13,796-foot summit of Mauna Kea, where they enjoyed tours of the Subaru Telescope before and during the transit. The rest of us set up our gear at the Onizuka visitor center, at an elevation of 9,300 feet. During the 6½-hour transit, various other people went to the summit for tours of Subaru. I had visited the summit in 1999 and 2007, so I decided to stay put at the visitor center.

A western ridge blocked the final hour of the transit from the visitor center, so most people in our group rode back to our beachfront hotel in Waikoloa and watched egress over the Pacific. The rest stayed behind and watched the finale from the summit. My only disappointment for the day was that the Sun set in a distant fog bank, ruining any chance of seeing a green flash.

I found it interesting that observers using hydrogen-alpha filters (including me) saw first contact about a minute before observers using standard white-light filters did; we also saw fourth contact about a minute after the white-light observers saw it. These bonus 2 minutes were due to the fact that H-alpha scopes show the chromosphere, which is above the photosphere.

I want to thank Neil Bauman and Theresa Mazich of Insight Cruises for an extremely well-organized trip, along with our guides: Charlie Datin, Aaron Melendrez, and Curt Duffy. A special thanks goes out to Wayne Fukunaga and Star Gaze Hawaii for providing 18 additional scopes and continual weather updates.

Robert Naeye
Editor in Chief

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Come and See

Thank you for Thomas Watson's Focal Point, "With My Own Eyes" (May issue, page 86). As a Solar System Ambassador with NASA's Jet Propulsion Laboratory and an amateur astronomer, I hear some of the same comments against spending time observing: the professionals have been doing it for years, so why bother? Yet there's nothing like the thrill of locating objects in the night sky, and as Watson argued, observing fulfills the need to see these wonders for myself. That is all the meaning I need. For several years now I have attended astronomy camps on Mount Lemmon near Tucson, sponsored by the University of Arizona Alumni Association. Each time is as "meaningful" as the last.

Janet S. Howard
Memphis, Tennessee

Watson's remarks touch upon a vital, joyful, and universal human experience, one to celebrate and to encourage. There is no substitute for seeing for ourselves.

Last summer I used a pair of 28×110 binoculars to show my nephews and their wives their first-ever sight of M6 and M7. I have yet to see many deep-sky objects, so at this stage I still do astronomy "backwards" — I go out and look without knowing what I am seeking and find out what the objects are afterwards. This was true for me when I stumbled across M35, M36, M37, and M38 at the Okie-Tex Star Party at Black Mesa, Oklahoma, a little after 5:00 a.m. one year. As Jimi Hendrix sang, "Scuse me while I kiss the sky!"

When our first granddaughter is old enough, I'm going to show her M41.

Clyde Glandon
Tulsa, Oklahoma

The Dark Sky Frontier, Reprise

I thoroughly enjoyed Tyler Nordgren's article "Astronomy in National Parks" (May issue, page 26). Not only is it well-written, the accompanying photos are breathtaking.

The national parks are indeed at the frontier of popularizing observational astronomy and raising awareness of the problem of (and solutions to) light pollution. I volunteer each September for the astronomy program at Acadia National Park in Maine, which Nordgren mentioned. As part of its Annual Night Sky Festival, the park throws a major star party on Cadillac Mountain. The party was rained out in 2011, but in 2010 it was attended by more than 1,000 park visitors and locals, a jump from the previous year's 300 or so. These numbers are only a small indication of the increased public awareness we are experiencing thanks to the untiring efforts of folks like Nordgren and the dedicated rangers in the National Park Service. I hope *S&T* will continue to keep these efforts in the public eye.

Bert Probst
Bay Village, Ohio



The glow from Northeast Harbor and Southwest Harbor looks like sunset in this shot of the Milky Way from Cadillac Mountain.

TYLER NORDGREN

Write to Letters to the Editor, *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, or send e-mail to letters@SkyandTelescope.com. Please limit your comments to 250 words.

I loved the piece on national parks and the emphasis it places on preserving dark skies. Sadly, it's the overnight camping that keeps many of us away. Those of us living within a few hours' drive of Zion National Park had a rare chance in the last few months, though: Utah Highway 14 washed out last fall, and since then the National Park Service has left the park gate open at night to allow area residents easy access to Hwy 89. Hwy 14 opened on a limited basis at May's end, and construction should be complete this month, so our chance to see Zion's skies probably won't last much longer. Last time I drove through, the night skies were spectacular, and we didn't see a single car from one side of the park to the other.

Jason Couchman
Henderson, Nevada

I enjoyed your national parks article, but it missed many of the beautiful parks in the eastern United States. I am a member of the Smoky Mountain Astronomical Society, which is invited each year by the National Park Service to conduct a star party in the Cades Cove region of the Great Smoky Mountains National Park on the Tennessee-North Carolina border. Cades Cove is one of the most beautiful sites in the park, especially at night. The first star party was in 2005 and attracted approximately 120 attendees; last October's gathering attracted more than 850 people. We distribute our old *S&T* magazines at the event to anyone who wants them, and we think we have added to our society's membership as a result. Thank you for such a wonderful magazine.

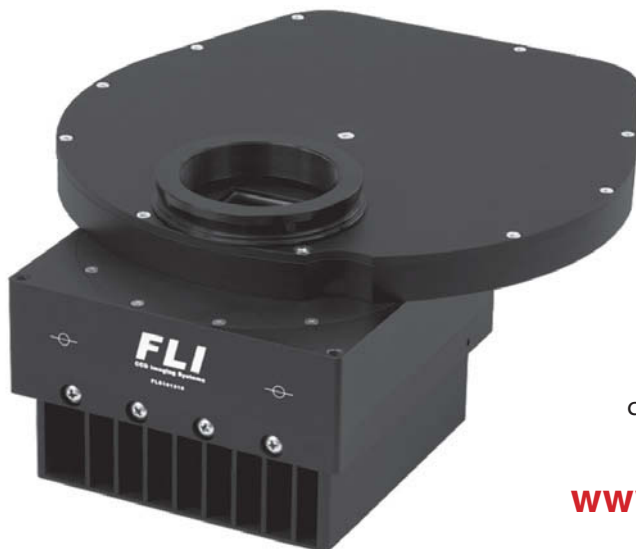
Duane Dunlap
Knoxville, Tennessee

Nordgren's article left out Rock Creek Park in Washington, D.C., which is, ironically, the only park in the National Park Service to have a planetarium. (It's part of the Nature Center.) I was the planetarium director there from October 2006 through



Lagoon Nebula Region in H α
ProLine PL16803 | John Gleason

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Letters

June 2009. The planetarium presents programs for the general public, as well as for school classes. For the last 50 years or so, RCP has collaborated with the National Capital Astronomers (of which I am currently a trustee) to present an "Exploring the Sky" event one Saturday evening each month from April through November. A few of us bring telescopes and we set them up for public viewing. Even though the sky is heavily polluted by lights from the District and neighboring Maryland cities, we usually get around 60 visitors.

Andrew W. Seacord, III
Bowie, Maryland

Call for Telescope Donations

Astrosphere New Media has started a telescope donation program in a partnership with Galileoscope that I'd like to bring to your readers' attention. Telescopes4Teach-

ers allows individuals and organizations to make tax-deductible donations and designate a school or teacher to whom Galileoscopes will be donated. We are very excited about this program, and hope that Astrosphere can meet its goal of putting 5,000 telescopes into classrooms by the time school starts in the fall. You can find out more at www.telescopes4teachers.org.

Douglas Arion
Galileoscope LLC

For the Record

★ In the bottom zoom image on page 51 of the July issue, R Draconis is the faint dot 1.5 mm below and left of the star indicated. The top image on the same page is correct.

★ In the August issue, pages 37 and 41, images credited to David Makepeace should have included Lukas Gornisiewicz in the credit or as the sole credit. See skypub.com/errata.

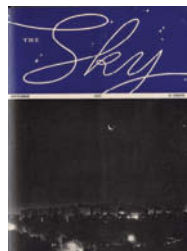
75, 50 & 25 Years Ago

September 1937

The Real Corona "The first definite proof that the solar corona is not made up chiefly of flaming coronal streamers alone, as has been supposed, but is an even, globular blanket covering the sun more than a million miles deep, was revealed [August 12] by a conference of astronomers at Harvard Observatory.

"Photographs leading to this finding were taken from an airplane in the stratosphere off the coast of Peru during the eclipse of last June 8."

Astronomers had expected airborne equipment to reveal more delicate tracery in the corona than is seen from the ground. Instead, it made the general glow stand out.



Roger W. Sinnott

often in less than a day, have added to the great interest Comet Humason has aroused among professional astronomers. To record these alterations, the 40-inch reflector of the U.S. Naval Observatory is especially effective. Elizabeth Roemer writes . . . 'I think the corkscrew feature in the tail on July 7th is real.'

Then shining at 8th magnitude from well outside Mars's orbit, this peculiar comet remains in a class of its own.

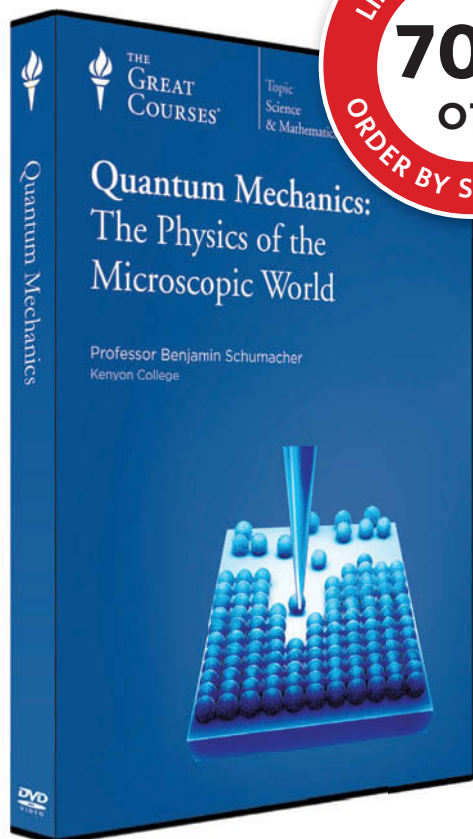
September 1987

Still No Planet X "The twin Pioneer 10 and 11 spacecraft have found no evidence for a planet beyond the orbit of Pluto. . . . [P]recise tracking data indicate that neither probe has felt the gravitational pull of an unseen body while racing through the outer solar system. . . .

"[A]pparently reliable 19th-century observations of Uranus and Neptune show that their orbits were slightly erratic. . . . Pluto and its moon aren't massive enough to have shifted Uranus and Neptune by the amounts seen. But if a larger planet [than Pluto] were responsible, why didn't it affect the Pioneers?"

Those 19th-century observations weren't so reliable: subtle flaws mimicked a Planet X's effect.





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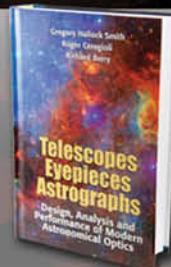
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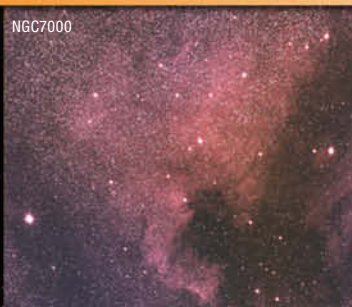
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M104



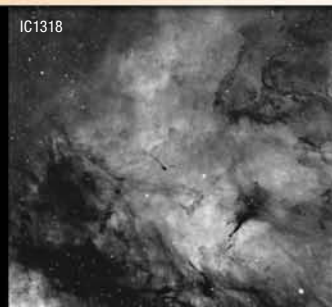
NGC7000



Jupiter



IC1318



M65, M66 and NGC 3628



Image by Ray Stann with EdgeHD Optics at f/7

Image by Jason Fournier with EdgeHD Optics at f/2

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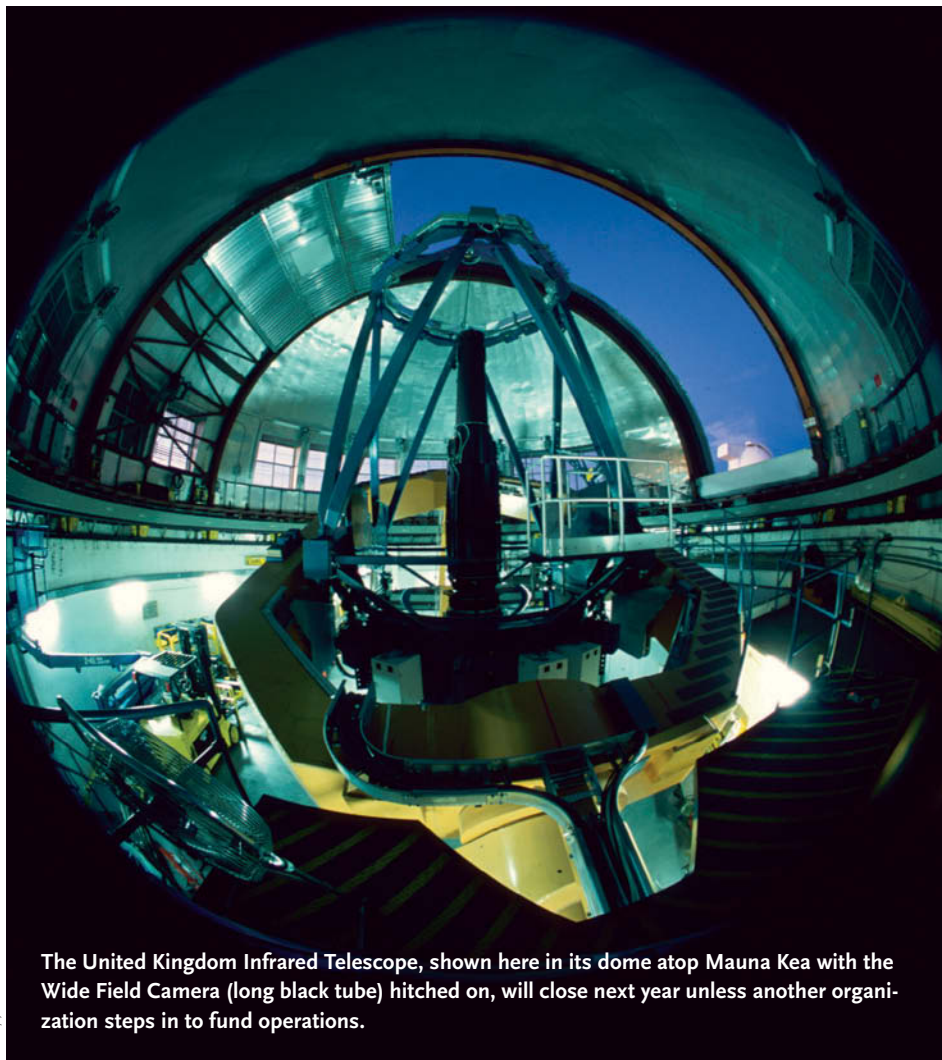
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SCOPES | Closure Nears for Two Hawaiian Observatories



The United Kingdom Infrared Telescope, shown here in its dome atop Mauna Kea with the Wide Field Camera (long black tube) hitched on, will close next year unless another organization steps in to fund operations.

UKIRT / JAC

Faced with too many telescopes and too little funding, officials at the United Kingdom's Science and Technology Facilities Council announced they will soon close two of the oldest observatories atop Mauna Kea. Unless another organization takes over operations, the United Kingdom Infrared Telescope (UKIRT) will shut down in September 2013, and the James Clerk Maxwell Telescope will close the following year.

It's becoming an all-too-common scenario in an era of shifting priorities and diminished funding for scientific

endeavors. The U.K. will still participate in several megaprojects, including the Atacama Large Millimeter/submillimeter Array (ALMA) and the proposed European Extremely Large Telescope, both in Chile. But those buy-ins leave little cash to maintain the country's older but still-productive facilities in Hawaii and the Canary Islands. (The STFC decision spares the U.K.'s three Canary scopes.)

The news wasn't unexpected: STFC signaled its intentions in late 2009. But it's still a sad turn of events. UKIRT's board claims that the scope's early closure will

bring an abrupt end to an ongoing deep-infrared survey that could have continued for an additional year using a budget of only about \$150,000.

With an aperture of 12.5 feet (3.8 meters), UKIRT ranks as the world's second-largest telescope dedicated solely to infrared observations (surpassed only by the U.K.'s recently built VISTA telescope in Chile). The James Clerk Maxwell Telescope has a primary mirror 49 feet (15 meters) across, making it the largest telescope optimized for observing at sub-millimeter wavelengths. Built by the U.K., Canada, and the Netherlands, JCMT saw first light in 1987; UKIRT, in 1979.

What's transpiring in the U.K. could be a harbinger of equally unwelcome events on this side of the Atlantic. A panel of U.S. astronomers is wrapping up a "portfolio review" for the National Science Foundation, and when the group releases its findings (slated, as we went to press, for late this summer), many suspect legendary facilities such as Kitt Peak National Observatory might get the ax.

Perhaps the novel arrangement NASA has struck regarding the Galaxy Evolution Explorer (GALEX) mission will become more common. NASA has turned both the spacecraft's control and funding over to a private institution — namely Caltech. The transfer, a first for NASA, is permitted by the Stevenson-Wydler Technology Innovation Act of 1980, which encourages federal agencies to transfer no-longer-needed resources to educational institutions and nonprofit organizations. Caltech plans to fund the 9-year-old spacecraft through domestic and international partnerships. So far, the institution only has a few months' worth of costs spoken for, but the number of partners will hopefully go up.

■ J. KELLY BEATTY



To get astronomy news as it breaks, visit skypub.com/newsblog.

EXOPLANETS | Metal-Poor Stars Parent Small Planets, Too

Astronomers have found that planets of less than four Earth radii can form around stars with a wide range of heavy-element abundances — even those stars with as little as one-fourth the Sun’s “metal” content. (In astronomy, “metals” are elements heavier than hydrogen and helium).

The results, announced by Lars Buchhave (University of Copenhagen) and his colleagues at the American Astronomical Society’s summer meeting and published in *Nature*, appear to run counter to two decades of ground-based observations that suggest metal-rich stars are more likely to harbor planets, particularly gas giants like Jupiter. But the new study doesn’t actually contradict those findings: although the team found small planets circle a variety of stars (with an average metal content close to the Sun’s), stars hosting gas giants still had metallicities on average 40% higher than the solar value.

Metals are mostly created inside stars. Because planets pull their raw material from the same source as their parent

Forming planets hide in gaps in this artist’s conception of a new star’s swirling protoplanetary disk of dust and gas.

stars, astronomers think the earliest stars (which were metal poor) probably didn’t host planets. Instead, planets arose later as the stellar population matured and built up stores of carbon, silicon, and oxygen — elements common in rocky planets.

But if small planets don’t require high metal content, planets may have started forming early in galactic history. That could mean more planets in general, but also more worlds that have had time for complex life to evolve.

Most of the 226 planet candidates in the study, all found by NASA’s Kepler mission, orbit within 0.5 a.u. of their stars. For many stars, planets with such tight orbits are probably not within the habitable zone.

“We can now look at basically any star, and there’s a chance it will have a small planet,” says coauthor Guillermo Torres (Harvard-Smithsonian Center for Astrophysics). “This really opens up the possibility for searches for habitable planets.”

■ **STEPHEN P. CRAFT**

NASA | Astronomers’ New Spy Scopes

It turns out charity isn’t dead in the government’s bureaucratic hallways. Astronomers recently announced that a federal intelligence agency has given NASA a pair of declassified space telescopes, at no charge. But like a car won on a game show, this gift isn’t exactly free.

Unofficially dubbed NRO-1 and NRO-2 (they belonged to the National Reconnaissance Office, but they never made it beyond the warehouse), the telescopes represent a unique opportunity to advance science with minimal impact on NASA’s beleaguered bottom line.

Launching both NRO scopes into space is currently beyond any NASA accountant’s dreams. But using one scope could help move forward the Wide-

Field Infrared Survey Telescope (WFIRST) project, a mission at the top of astronomers’ decadal wish list (*S&T*: March 2011, page 22). WFIRST was envisioned to address several high-priority science programs, including investigating dark energy and hunting for exoplanets. No instrument has been built yet, but the project was pitched as a 1.5-meter wide-field telescope.

That’s a shoe NRO-1 could easily step into. Though designed for terrestrial viewing, both scopes are “optically perfect,” says Alan Dressler (Carnegie Observatories), who briefed politicians in June on potential uses for the scope. Each scope sports a $\frac{1}{2}$ th-wave, 2.4-meter (7.9-foot) primary mirror, with a field of view about 100 times larger than that

of the Hubble Space Telescope. Depending on the doohickeys NASA adds, a repurposed NRO could have a field of view about the same as WFIRST’s but could see objects twice as faint.

That capability would make it a good partner for the oft-delayed James Webb Space Telescope. With a larger field of view but lower sensitivity, NRO-1 could pick out interesting infrared targets through surveys that JWST could then home in on.

But NRO-1 is far from ready to launch. The telescope is basically optics and housing, without instruments. It also needs a body and a ride to space.

With the Space Shuttle Program terminated, the ride might be the biggest problem. But NRO-1 is lighter than Hubble and thus less

expensive to launch. Dressler speculates that tests of NASA’s Space Launch System might provide a serendipitous way to lift NRO-1 into orbit; private-sector launch vehicles such as SpaceX’s Falcon 9 could work as well.

Dressler estimates each of these obstacles will cost \$100 to \$200 million to overcome. Still, the optics and housing — which NASA now has — make up the bulk of telescope-building costs. NRO-1 might be put into service for \$1 billion, an amount roughly one-third Hubble’s pre-launch construction bill in 2012 dollars.

Still, NASA’s astrophysics budget is tied up in the (currently) \$9-billion JWST. Assuming JWST deploys by 2018, NRO-1 could be put into service by 2020 to 2022.

■ **STEPHEN P. CRAFT**



UNIVERSITY OF COPENHAGEN / LARS A. BUCHHAVE

INTERSTELLAR SPACE

No Bow Shock at Solar System Boundary

Measurements from NASA's Interstellar Boundary Explorer (IBEX) suggest that the Sun doesn't fly fast enough through space to create a bow shock in the thin gas floating between the stars. This bow shock has been a long-standing pillar of scientists' understanding of the solar system, and the new result may overturn decades of research.

Technically, the solar system's edge lies where the solar wind slams into interstellar gas. At this point the heliosphere, the vast magnetic bubble created by the solar wind, hits the (also magnetized) interstellar medium. Because the interstellar medium's magnetic fields are aligned differently than those of the heliosphere, the meeting of solar wind and interstellar particles is like oil and water: a boundary appears.

Scientists thought the Sun flew through space like a supersonic jet, creating a bow shock as the heliosphere plowed through the interstellar medium, much like the air pileup in front of a fighter plane. But an international team reported in the June 8th *Science* that the Sun is moving through this gas at 52,000 miles (84,000 km) per hour, about 12% slower than the speed previously measured by the Ulysses spacecraft.

That slower speed makes the Sun look less like a fighter jet and more like a cruising boat. IBEX's observations confirm that the Sun is still moving through the Local Interstellar Cloud, a fluff of gas roughly 30 light-years across. But combined with the effect of the interstellar medium's relatively strong magnetic field, the Sun's slower advance makes at best a bow wave, a region of slightly increased density like that around a chugging tugboat.

"It's too early to say exactly what these new data mean for our heliosphere," says IBEX principal investigator David McComas (Southwest Research Institute, San Antonio). "Decades of research have explored scenarios that included a bow shock. That research now has to be redone."

■ MONICA YOUNG



NASA / JPL / UNIVERSITY OF ARIZONA

MARS | Dunes on the Move

Scientists studying images from NASA's Mars Reconnaissance Orbiter have caught dunes migrating across the Red Planet's surface. Common wisdom dictates that winds in the planet's thin atmosphere can't deliver the strong, sustained push needed to get sand moving on a large scale, but the new observations add to growing evidence that this assumption is wrong.

The team used two pairs of snapshots from the orbiter's High Resolution Imaging Science Experiment (HiRISE) camera to track dune migration in the equatorial Nili Patera dune field. The measurements, which were taken 105 Earth days apart, showed that dunes moved with an average speed of 0.1 meter per Earth year. Although that migration rate is one-tenth to one-hundredth the speed of terrestrial dunes with comparable heights, the average rate of sand transport — the volume of sand moved over a certain distance in a certain time — is about equal to that of dunes in Victoria Valley, Antarctica, the team reported in the May 17th *Nature*.

The result shows that Martian winds can easily send sand moving across the surface. What matters is not how hard it is for winds to pick up individual grains, but what happens when the dancing grains fall back down. Sand grains can fly higher and longer in Mars's low surface gravity, gaining more speed than

Ripples on dunes in Mars's Nili Patera region (shown here) moved as much as several meters over 105 Earth days. The ripples' movement allowed researchers to calculate the dunes' migration rate, proving Martian winds can in fact move sand on a large scale.

they would have otherwise. When they come bouncing down again, they smack into other grains and get them moving, too. Mars's low gravity makes this easier to do, explains Candice Hansen (Planetary Science Institute), who last year reported evidence for dune changes in the north polar region but was not involved with the current study.

Ultimately, after a few gusts kick up some grains, moderate winds could keep the dunes moving across the landscape. The result implies that Nili Patera could have formed in less than 10,000 years, an interpretation contrary to the long-standing idea that Mars's dune fields formed in a previous climate with a thicker atmosphere.

The new explanation for sand's migration could partially explain the existence of global-scale dust storms (page 26), explains physicist Jasper Kok (Cornell University). Data from NASA's Mars Exploration Rovers also suggest that low-density clumps of dust are easier to lift than sand, but the full answer remains elusive, he says.

■ CAMILLE M. CARLISLE

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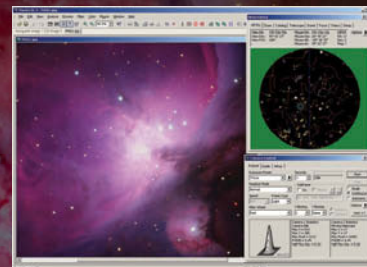
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PRO-AM | Millions of Stars and the Promise of More

A pro-am collaboration by the American Association of Variable Star Observers is producing a detailed photometric all-sky map that will fill a sizable hole in current data, AAVSO director Arne Henden announced at the American Astronomical Society's summer meeting.

The AAVSO Photometric All-Sky Survey (APASS) uses five filters to observe stars between 10th and 17th magnitude in both hemispheres (*S&T*: June 2011, page 34). This magnitude range has never before been systematically surveyed, although it partly overlaps previous all-sky work in photometry and astrometry, the latter including observations by the U.S. Naval Observatory's UCAC program. The pro-am team also chose these magnitudes because they are ones typically observed in backyard telescopes.

Observers will likely still need to rely on photometric data taken with bigger telescopes for the most crowded parts of the sky, says Brian Skiff (Lowell Observa-

tory), who has spent several years compiling his own database of high-quality photometry. "But even within its limits, [APASS] should be a boon for observers — both professional and amateur — doing systematic observing of just about any sort," he says.

Having standardized, high-precision photometry for these stars will enable astronomers to more accurately (and more quickly) determine magnitudes for variable stars or for new objects such as supernovae. With 42 million stars covered by APASS, observers won't have to spend as much time searching the sky or their images for a comparison star. "Folks have wanted a uniform survey like this for a long time," says Skiff.

APASS uses two pairs of 8-inch astrographs, one in New Mexico and the other in Chile. Each pair sits on a Paramount ME mount and is operated remotely. One scope takes the bluer Johnson B and Sloan g' exposures, and the other snaps the red-

der Johnson V and Sloan r' and i' shots. Each image is $2.9^\circ \times 2.9^\circ$ in size; so far, the survey has covered roughly 95% of the sky twice.

APASS uses solely commercial hardware and software, working largely thanks to vendor support and private grants.

Henden says APASS's photometric precision is currently about 3%. He expects that to improve to 1 to 2% by the final release of the catalog in 2014.

Also on the pro-am scene, a promising new program is Lowell Observatory's Lowell Amateur Research Initiative (LARI), announced at this year's Symposium on Telescope Science in Big Bear Lake, California. LARI seeks to take advantage of amateurs' enthusiasm and skills by assigning applicants to projects suited to their interests and capabilities. You can find a list of projects currently open to collaborators on LARI's site at <http://bit.ly/K2z9Wo>.

■ CAMILLE M. CARLISLE

GALACTIC | M31-Milky Way Crash No Fender-Bender

New work using Hubble Space Telescope observations of the Andromeda Galaxy has found that the galaxy will possibly collide head-on with the Milky Way in about 4 billion years. The conclusion, reported in three papers in the July 1st *Astrophysical Journal*, used detailed measurements of M31's proper motion to pin down the galaxies' possible fates. Uncertainty in previous proper motion measurements had left astronomers dubious about the exact nature of the expected pile-

up. Now, the precise HST measurements, coupled with careful computer simulations, suggest that M31 and the Milky Way have a 41% chance of striking head-on (defined as a collision in which their centers are at most 82,000 light-years apart). In that case, the smaller galaxy M33, which currently orbits Andromeda, will settle into an orbit around the M31-Milky Way pair.

However, the authors add that there's a small chance (9%) that M33 will strike the

Milky Way first — or it might get flung from the Local Group altogether (7%). The collision will likely push the solar system farther out from the newly-formed galactic center than its current location in the Milky Way.

Based on the computer simulations, this image sequence shows what might happen as M31 and the Milky Way collide. The view is set 25,000 light-years from the Milky Way's center, roughly Earth's present galactic address. ♦

■ J. KELLY BEATTY



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New Meteor Showers Discovered



JUAN CARLOS CASADO



As Earth circles the Sun, it crosses a rich and changing tangle of meteoroid streams. Automated cameras are mapping them better than ever.

PETER JENNISKENS

FOR THE FIRST TIME in nearly two centuries of surveying the night sky, astronomers are charting meteor showers in a massive and objective way — by automated surveillance video. Generations of naked-eye observers have discovered and monitored meteor showers by visual counting and hand-plotting. Photography and radar have helped, but all these methods have their limits. Now we're using networks of low-light video cameras and sophisticated data processing to map meteoroid streams much better than ever before. We're finding dozens of new minor showers and some surprising not-so-minor ones. Amateurs are participating, and we're seeking more help in this ongoing effort.

Until now, astronomers have agreed on only a short list of 64 “established” meteor showers. At the August International Astronomical Union's General Assembly in Beijing, which will take place about two months after this issue goes to press, we expect to expand this official list greatly.

These developments are quite recent. Our Cameras for Allsky Meteor Surveillance (CAMS) project, first came online in October 2010. In just over a year it has identified new showers and confirmed many previously questionable ones that we hope will be approved in Beijing.

Tiny Bits Betray Big Parents

Each meteor shower is important, no matter how minor it appears. A shower happens when Earth, in its annual orbit around the Sun, passes through a sparse stream of sesame-seed to pebble-sized dust clods and bits of rock that have been shed by a mountain-sized comet or occasionally by an asteroid. This parent body follows an orbit similar to its debris stream, which means that even a minor shower can betray the presence of a comet that might someday hit Earth. Meteor showers indicate these potentially hazardous objects even if the parent has yet to be discovered. Showers also provide clues to what these objects are made of and how they have behaved in the recent past, how they shed particles when warmed by the Sun and, in many cases, at what times they have undergone massive disruptions.

If we can identify the source body, we can calculate the shape and size of the stream in space by determining how the parent was moving when each wave of shedding occurred, and how each swarm from these episodes has been gravitationally perturbed since. The current

searches for near-Earth objects have been identifying the parent bodies of numerous showers for the first time.

Over many millennia, a meteoroid stream gradually spreads out and falls apart, creating the great background of random sporadic meteoroids that impact spacecraft unpredictably and give rise to the solar system's vast zodiacal dust cloud.

Mapping the Meteor Year

To my surprise, the first week of December has turned out to be the most interesting for meteor observations. The new CAMS data show that at least 14 significant showers are active that week, each with its own particular radiant direction on the sky, velocity, duration (indicating stream width), and behavior. Five of these showers were completely new to me, even after spending many nights over the years on my back in a reclining lawn chair, pen and paper in hand, watching the sky intently.

That's how meteor showers used to be discovered. Since about the 1860s, visual observers have mapped them by drawing meteor paths on a star chart and then looking for a divergence point: the shower's radiant, its perspective point of origin on the sky. The radiant is where we would see a shower's meteoroids coming from if we could see them in the far distance, instead of just in their final second or two when they dive into the atmosphere. The particles in a stream move essentially in parallel — so like railroad tracks in a photograph, they appear to diverge from a distant perspective point.

Starting in the 1930s, astronomers have also identified showers not just by meteors' two-dimensional paths on the sky, but by their actual three-dimensional paths through Earth's atmosphere as triangulated from sky cameras positioned some 25 to 60 miles (40 to 100 km) apart. Working backward from this path through the atmosphere, we can determine a meteoroid's prior orbit through the solar system. But photographic film and plates were relatively insensitive, and such efforts produced few orbits. A great many showers were reported based on suggestive, but statistically weak, similarities among a mere two or three such calculated orbits.

The list of showers grew even longer in the 1940s, when radar was first used to count meteors and measure rough trajectories in the atmosphere. This was how astronomers mapped daytime showers. By that time,

however, meteor astronomers had often given up on checking their results against those of other researchers, and soon many showers were known by multiple names. Only in 2006 did the International Astronomical Union resolve this confusion by adopting nomenclature rules and establishing a Task Group on Meteor Shower Nomenclature, which I chair.

We name officially accepted showers for the constellation containing the shower's radiant, or the bright star nearest to it. The Latin possessive ending of the star name is replaced by "-id." For example, when Earth passes through Comet Halley's meteoroids in early May, we see them radiating from near the star Eta Aquarii, so they are called the Eta Aquariids (pronounced Aquari-ids). In case of confusion, the task group can propose a preference. Names are only official once a stream is convincingly established as real.

The Meteor Data Center in Poznań, Poland, maintains a Working List of Meteor Showers, which helps us keep track of known and suspected showers mentioned in recent literature. New shower discoveries need to be first verified against that list and are then assigned a unique name and three-letter code.

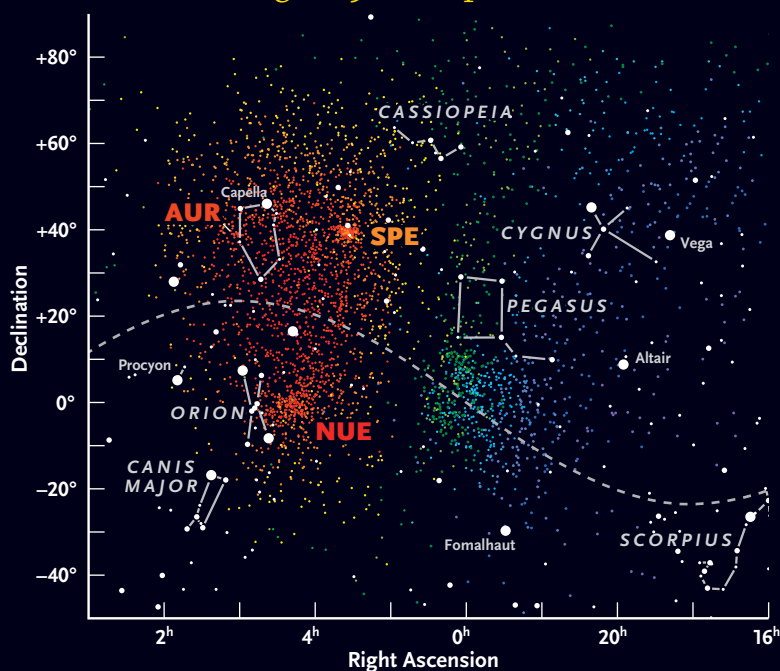
This working list was 385 showers long as of June. At the IAU General Assembly in Rio de Janeiro in 2009, 64 of them received official names and the designation "established." But that still left more than 300 showers awaiting confirmation.

The CAMS Project

CAMS grew out of my frustration in trying to construct a list of known meteor showers for my 2006 book *Meteor Showers and their Parent Comets*. Based on the literature, it was impossible to tell which ones were real beyond a handful of main showers.

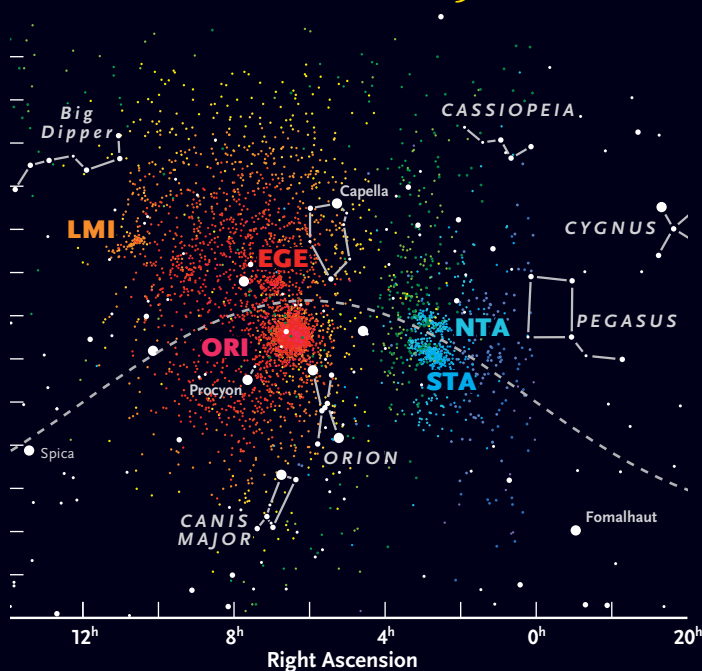
Each colored dot on these maps is the calculated radiant of a single meteor. Violet, blue, and green mark slow (11 to 45 km per second, or 25,000 to 100,000 mph) meteors that are catching up to Earth. Most of these come from Jupiter-family comets. Yellow, orange, and red dots mark fast (up to 72 km per second, or 160,000 mph) meteors that approach Earth head-on. They mostly come from Oort Cloud comets. A group of dots in the same map sharing the same color represents a specific meteor shower. Many of these are labeled with the official 3-letter IAU designation. The dashed line is the ecliptic plane. See more maps at skypub.com/cams. ALL MAPS S&T: GREGG DINDERMAN / SOURCE: PETER JENNISKENS

August 30 – September 12



The tight radiant clustering of the Aurigids (AUR), a shower observed by the SonotaCo project only in 2007, indicates a young shower. Our modeling shows that the 2007 outburst represents debris shed one revolution ago by the long-period comet C/1911 N1 (Kiess). The September Epsilon Perseids (SPE) and the Nu Eridanids (NUE) originate from unknown Oort Cloud comets. In total, this map includes 1,774 meteors from SonotaCo and 1,866 from CAMS.

October 18 – 29



For visual observers, the familiar Orionids (ORI), which are particles shed by Comet Halley, mask the faster Epsilon Geminids (EGE), which had been suspected from sparse photographic data but are now confirmed. The Leonis Minorids (LMI) originate from Comet C/1739 K1 (Zanotti). At this time of year, the Southern Taurids (STA) are more active than the Northern Taurids (NTA). These data are based on 7,604 meteors from SonotaCo and 1,629 from CAMS.

Since mid-2008, NASA's planetary-astronomy program has supported the CAMS project to confirm the unconfirmed showers. It took several years to develop the necessary technologies to deal with data from 60 video cameras divided over three stations. First light was in October 2010, and all stations were working by May 2011.

We analyze the data at the SETI Institute, my home institution near NASA's Ames Research Center. A team of 10 amateur astronomers support the data analysis and operate our video stations, located around the San Francisco Bay area. The first station is at the Fremont Peak Observatory south of Gilroy, California, and is run by amateurs of the Fremont Peak Observatory Association (FPOA). A second station is at a private home in Sunnyvale, currently with Jim Albers. The third is at Lick Observatory, operated by staff astronomer Bryant Grigsby.

How do we do it? Each station has 20 Watc Wat-902H2 Ultimate video security cameras aimed around the sky. These can see stars as faint as magnitude 5.4 when equipped with 12-mm objective lenses. Each camera watches a 20°-by-30° area, allowing 20 cameras to cover the entire sky above 30° elevation.

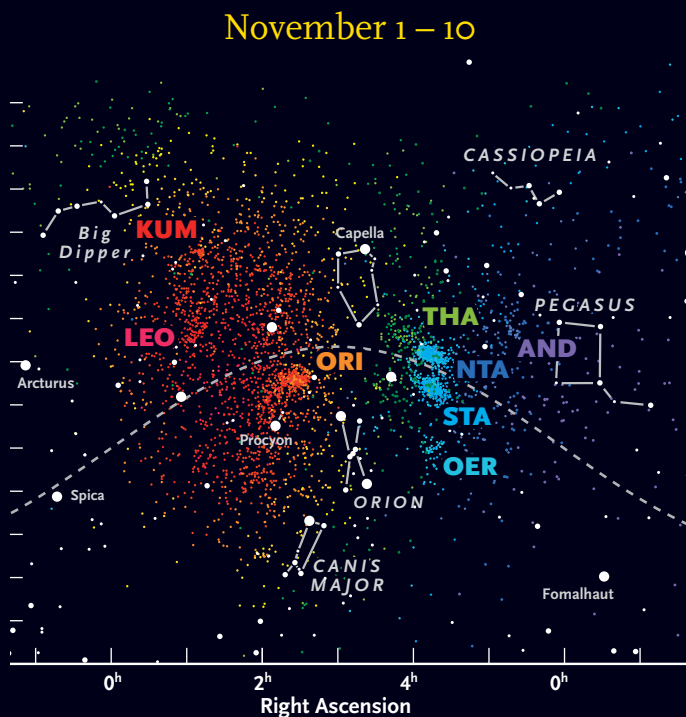
The heart of the project is the software needed to detect meteors in video recordings, triangulate on them from differ-

ent stations, and calculate their 3-D trajectories in the atmosphere and prior orbits in space. The main architect of this software is amateur astronomer and professional detection-algorithm specialist Pete Gural of Sterling, Virginia.

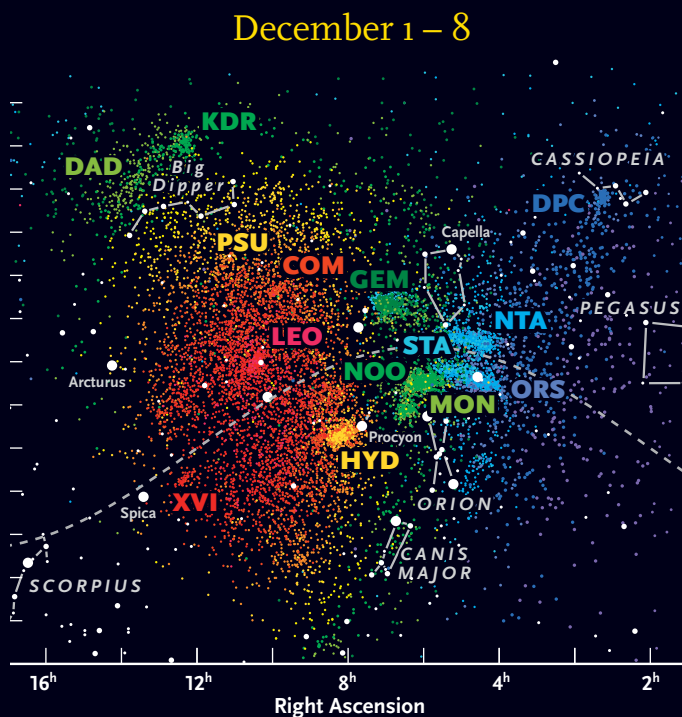
If you'd like to chip in and help, we have also developed the tools that enable you to run your own single-camera CAMS station. This effort is coordinated by FPOA member Dave Samuels. See the box on page 25 for more details.

Each camera generates about 10 gigabytes of video per clear night. Software examines the footage for meteors, and it saves only 8-second snippets that contain moving objects. That still means that each camera collects about 200 megabytes of data per night.

I collect the 60 cameras' video records for processing at the SETI Institute. One software tool maps each camera's field of view based on the star background. Another extracts meteor trajectories and speeds. Software then looks for coincidences: the same meteor filmed from at least two stations. I check the quality of each coincidence to exclude birds, bats, clouds, planes, and other false matches that the software has not already filtered out. The final product is a reliable table with all trajectory and orbit information, plus light curves.



Showers in early November include late Orionids, early fast Leonids (LEO), the Northern and Southern Taurids in about equal numbers, the newly discovered Kappa Ursae Majorids (KUM), Omicron Eridanids (OER), and the slow Andromedids (AND). Morning-sky radiants produce faster meteors than those in the evening sky because they collide with Earth head-on. Evening-sky meteors come from the other direction. There are 2,474 meteors from SonotaCo and 2,140 from CAMS.



The first week of December sports 14 distinct showers at present count. The once-unknown Sigma Hydrids (HYD) swell to become a major shower on December 6th. Their parent body remains undiscovered. The November Orionids (NOO) run from mid-November through mid-December. Some early Geminids (GEM) are already showing up. Leonids are seen continuing well past their November 17th peak. There are 4,250 meteors from SonotaCo and 3,240 from CAMS.

Most other all-sky meteor networks focus on catching fireballs that might drop meteorites on the ground. These record only a few meteors per night from which we can extract good orbits. Our goal for CAMS was to scale up the harvest.

Most of the meteors we detect are magnitude +1 to +3, the same that visual observers generally see. When all the cameras operate as expected, we determine 100 to 300 meteoroid orbits on a clear night. We now have collected more than 47,000 orbits.

CAMS is producing as many orbits each clear night as the original three-year tally published from a similar effort by the Japanese SonotaCo consortium, led by Tsuru Kanamori of Tokyo. That ongoing project started in 2007 and is expected to produce many more orbits in the future. The SonotaCo network consists of 25 amateur astronomers who operate up to 100 cameras with about a 90° field of view, recording slightly brighter meteors. Because of our smaller field of view and higher spatial resolution, CAMS measures orbits about twice as accurately.

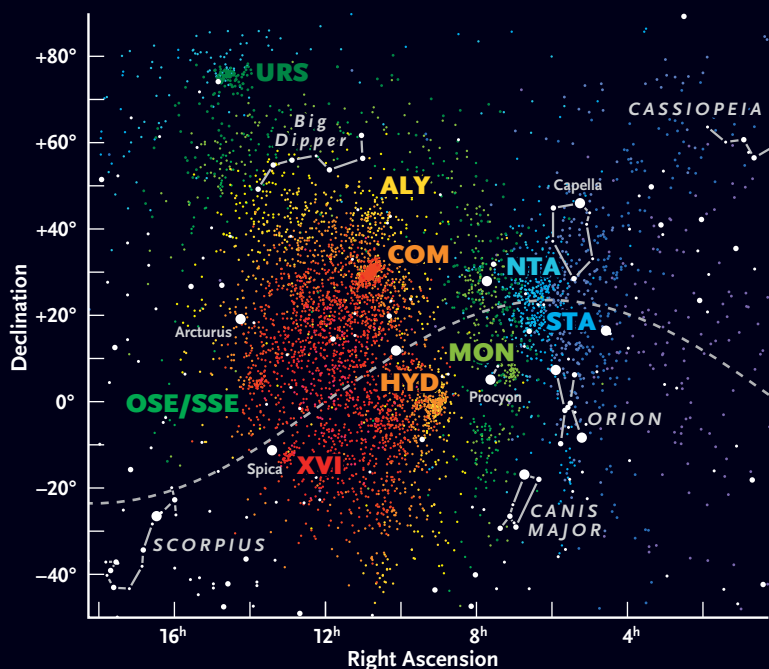
“Established” Showers

Together, SonotaCo and CAMS are giving us a better picture than ever of which meteor showers are active around the year, and how showers change from year to year.

To display the 64 showers officially established so far, I made 15 maps for spans of several days using combined SonotaCo and CAMS data. Some of these maps are shown in this article; all can be seen at skypub.com/cams. Each colored dot is the calculated radiant of a single meteor. Color indicates the meteor’s arrival speed, from violet for the slowest to red for the fastest. A group of same-colored dots indicates a shower, often with its three-letter designation. The maps also identify some previously unconfirmed showers seen clearly in the CAMS data; we expect that these will soon receive the label “established.”

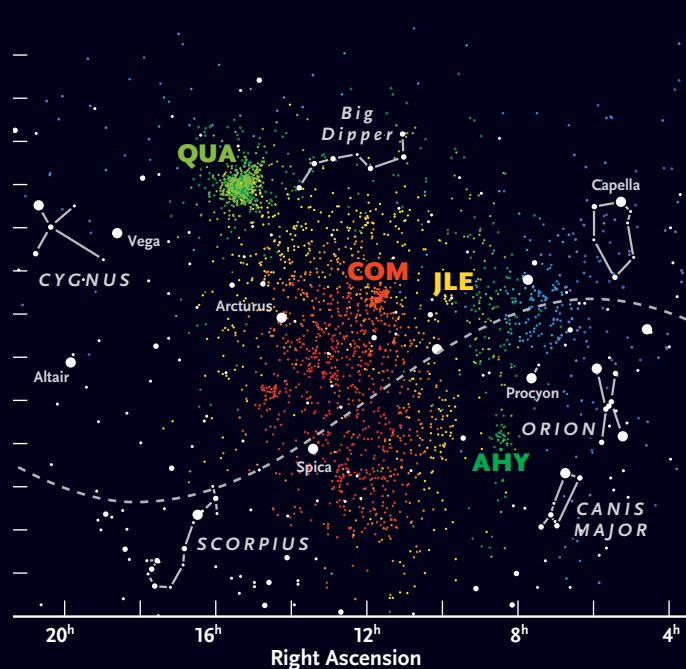
CAMS also picked up many previously unknown showers, and some were detected well enough to deserve “established” status right away. For example, six meteors with one ultra-compact radiant appeared within a few hours on February 4, 2011. This radiant was not there in earlier years. Now called the February Eta Draconids, this shower was caused by Earth briefly being hosed by the first-revolution debris trail of a previously unknown long-period comet. Because the bits were released only at the comet’s last return, the radiant swarm is very concentrated. The stream is the first evidence of this comet’s existence, and the fact that we were briefly showered by its first-revolution debris tail implies that the comet could potentially hit Earth.

December 18 – 25



The Ursids (URS), originating just off the bowl of the Little Dipper, come from the Halley-type Comet 8P/Tuttle. The December Comae Berenids (COM) peak this week, but the shower is active all December and January. Radar observations had earlier found the daytime Omega Serpentids and Sigma Serpentids (OSE and SSE); the CAMS project confirmed them with a few meteors seen coming from these radiants before dawn. There are 2,792 meteors from both SonotaCo and CAMS.

January 1 – 7



In the year’s first week, the brief but rich Quadrantid (QUA) shower sends medium-speed meteors radiating from near the Big Dipper. These originate from the asteroid-like object 2003 EH₁, a dormant Jupiter-family short-period comet that suffered a breakup about 500 years ago. Other identified showers are the Comae Berenids, the January Leonids (JLE), and the Alpha Hydrids (AHY). Note the hints of additional clumps. There are 2,831 meteors from SonotaCo and 381 from CAMS.

Also, while reducing CAMS data for this article, I discovered a shower of very slow meteors (16.7 kilometers per second, or 37,400 mph) radiating from Cassiopeia in early December and originating from a Jupiter-family comet. From what I can tell, nobody has ever heard of it. It has been designated the December Phi Cassiopeiids (code DPC).

Even with more than 100,000 orbits now measured by CAMS and SonotaCo combined, the sky is still sparsely sampled. CAMS maps of single nights are clumpy, suggesting that unrecognized showers lurk just below the threshold and are awaiting better data. In the next two years we hope that CAMS will bring these showers into focus.

And we hope that readers will set up single-CAMS stations to create a wider surveillance network, and to help ensure that video surveillance of the night sky will continue. With some of the more interesting showers showing up only once in a while, the future will surely be rich with surprises. ♦

Peter Jenniskens is a meteor researcher with the SETI Institute and NASA/Ames Research Center. He chairs the IAU Task Group on Meteor Shower Nomenclature and is author of "the" book on the topic, Meteor Showers and their Parent Comets.



SGT. ROBERT NAEYE



CAMS VOLUNTEERS Above: At the College of San Mateo, just south of San Francisco, California, observatory director Dean Drumheller (left) and astronomy and physics professor Darryl Stanford (right) operate the skyward-pointed CAMS meteor camera on the wall behind them (inset photo at left).



WATEC



FUZHOU DC-VIDEO EQUIPMENT CO.

SHOPPING LIST The main items you'll need to buy to join the CAMS project are a Watec Wat-902H2 Ultimate low-light security camera (a standard weatherproof housing is also recommended), a 12-mm f/1.2 fixed-focus lens for it, and the EasyCap frame grabber for your computer's operating system.

Join Us! How to Set up a Single-CAMS Station

My colleagues and I urge amateurs to participate in the CAMS project. You can set up a camera at your own location to help determine meteoroid orbits with the same precision as the main part of CAMS, using the same tools.

First, find at least one friend 25 to 60 miles away who will join the project. A single CAMS camera can detect about 50 meteors per clear night. Two cameras spaced appropriately can allow us to measure about 10 to 20 accurate orbits per night.

Each station needs a Watec Wat-902H2 Ultimate camera, a 12-mm f/1.2 lens for it, an EasyCap frame grabber, a video cable, access to power, and a PC. The cameras should be aimed at the same volume of the atmosphere about 50 or 60 miles up. They can be mounted outside in a standard weatherproof security-camera housing (recommended), or indoors behind a window in a dark room. The computer needs to be dedicated to the project during capture hours. The combined cost of the camera, lens, frame grabber, and cable is less than \$600.

It takes about an evening's work to set up the system. Some experience with running Windows console programs and scripts is helpful. After that the system can work almost by itself, with

scripts running the various software tools at the appropriate times.

After everything is set up and calibrated, the camera will automatically begin recording each night. A fast multi-core computer can process the video as it comes in and finish a few minutes after recording stops at dawn. Slower computers will need to run the software later, which can take 3 to 8 hours. Finishing and uploading the results takes less than a half hour per week of clear nights. The average data upload you need to send us is just 2 to 6 megabytes per clear night.

See cams.seti.org/easyCAMS.html for more.



EASYCAP

Nature's Wrath



The solar system's wild weather can make Earth's own extremes seem serene.

David Baker & Todd Ratcliff

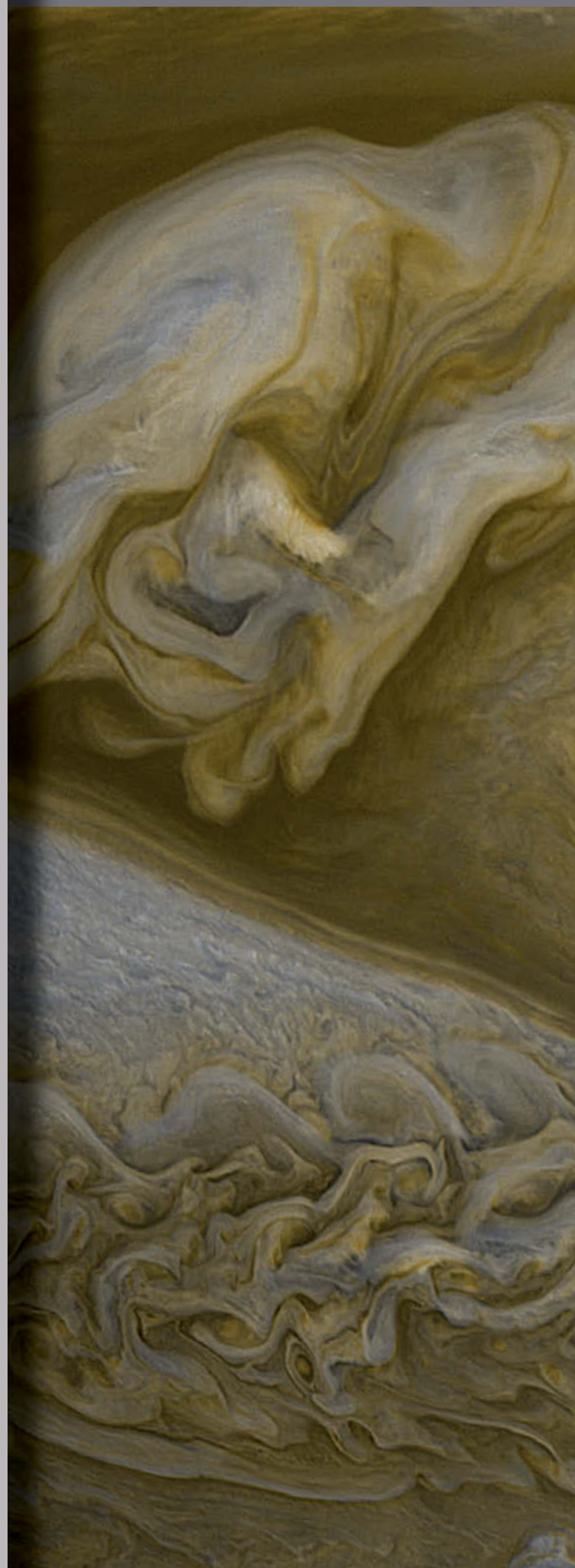
“Can you believe this weather?”

It's more than just small talk. Weather significantly impacts our daily lives. Food, clothing, shelter, heating and cooling, work, play, transportation, communications, and health are all intimately affected by it. There is nothing superficial about the weather.

Earth's dynamic weather is ultimately the product of temperature gradients. A pleasant sea breeze at the beach is created by temperature differences between land and water. Refreshing rain showers can develop when unstable hot air rises up from the surface and cools, allowing the water in it to condense. Even on the global scale, energy imbalance between the equator and poles drives worldwide atmospheric circulation.

Yet Earth's attempt to equilibrate its temperatures doesn't always go smoothly. Violent twisters rip through Tornado Alley when warm, moist air from the Gulf of Mexico collides turbulently with cool, dry air from the north. Lightning sizzles at 28,000°C (50,000°F, nearly five times hotter than the Sun's surface) and damages more than \$1 billion in property each year. Tropical cyclones such as Hurricane Katrina, with sustained peak winds of 78 meters per second (175 mph) and an ocean storm surge more than 10 meters (33 feet) high, ravage unprotected coastlines and damage delicate ecosystems.

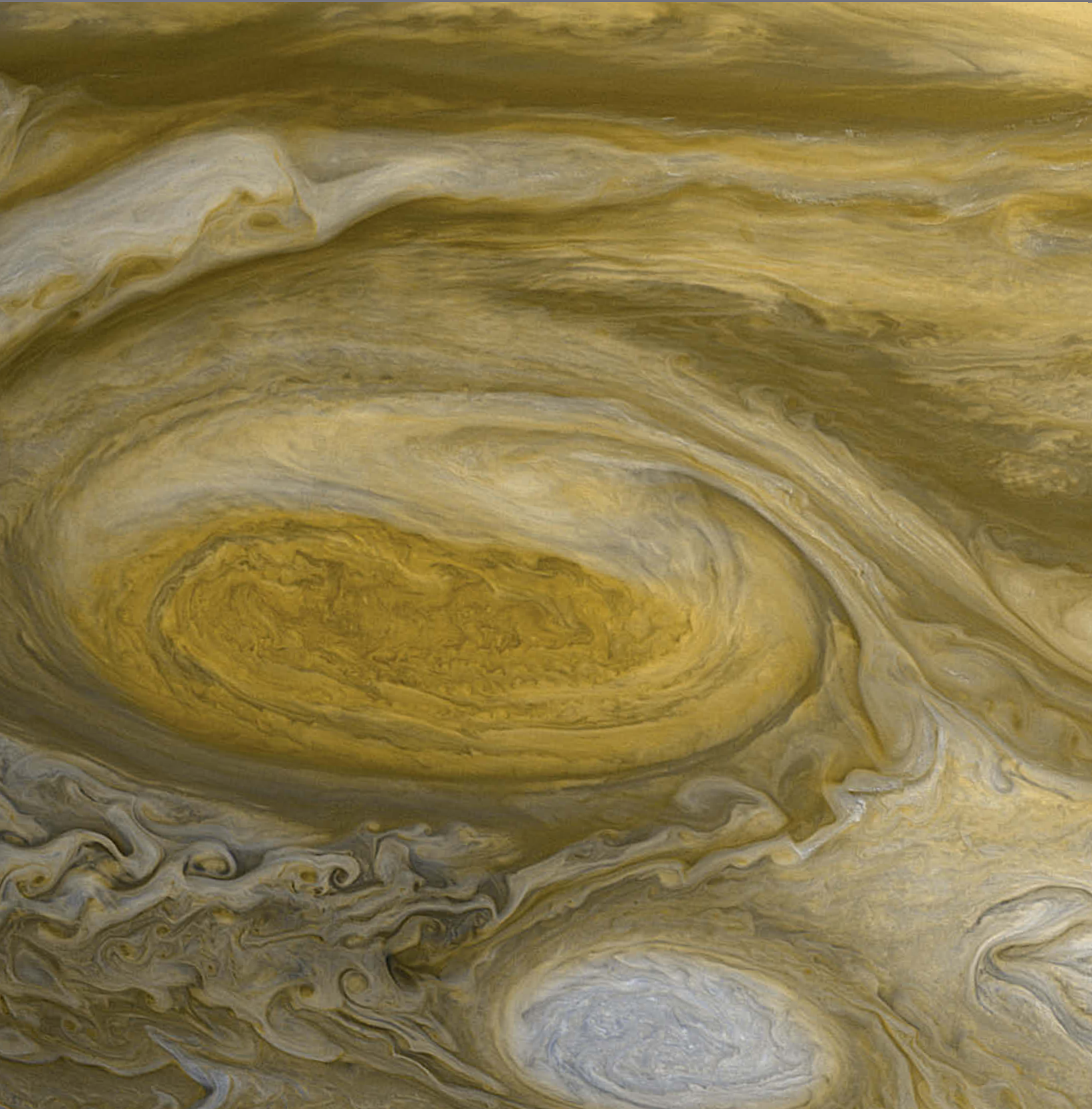
Due to the chaotic nature of Earth's atmosphere, forecasting weather can be challenging. Small fluctuations in the atmosphere can lead to hefty weather changes later because of the complex ways wind, tempera-



Left: Tracks left by dust devils' passage on Mars appear bluish in this color image from the Mars Reconnaissance Orbiter's HiRISE camera.

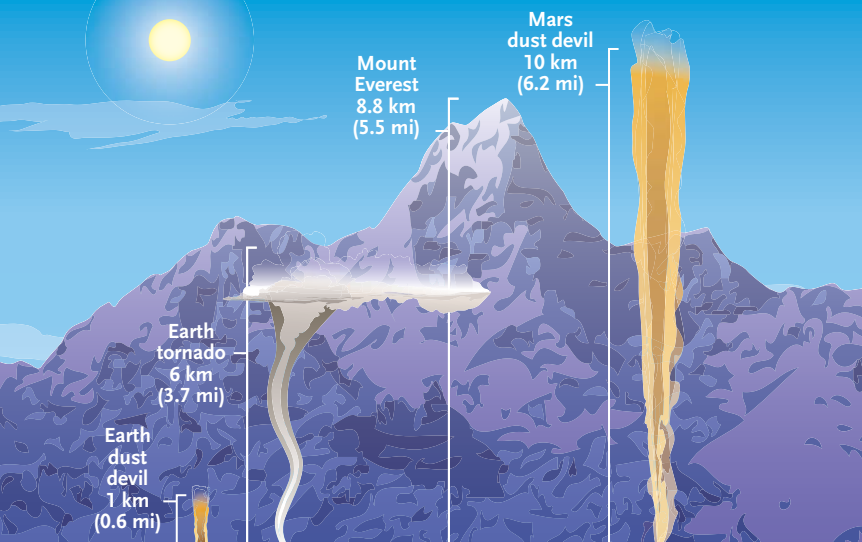
ALL IMAGES OF DUST DEVIL TRAILS: NASA / JPL / UNIVERSITY OF ARIZONA

This mosaic combines 24 images of Jupiter's Great Red Spot taken by the Voyager 1 spacecraft on March 4, 1979, when the spacecraft was 1.9 million kilometers (1.2 million miles) from Jupiter.



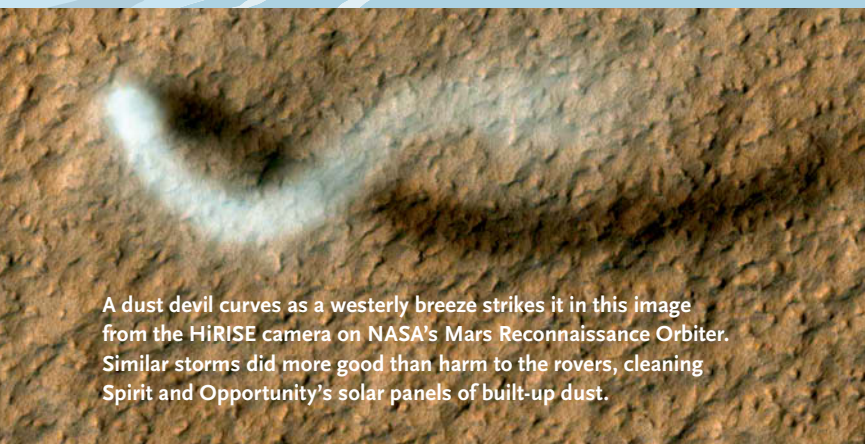
NASA / JPL, DIGITAL PROCESSING: BJÖRN JONSSON

Alien Storm Chasing



S&T: LEAH TISCIONE

Martian dust devils can easily rise 10 km high, towering above similar vortices on Earth. Terrestrial tornadoes may extend 6 km into the sky, although that's something of a guess: what constitutes the top of a tornado isn't universally agreed upon, so height estimates vary.



A dust devil curves as a westerly breeze strikes it in this image from the HiRISE camera on NASA's Mars Reconnaissance Orbiter. Similar storms did more good than harm to the rovers, cleaning Spirit and Opportunity's solar panels of built-up dust.



Seen on March 14th this year by HiRISE, this gargantuan dust devil towered 20 km (12 miles) above the Martian surface as it swept across the northern region of Amazonis Planitia.

NASA / JPL-CALTECH / UNIV. OF ARIZONA (2)

ture, and moisture interact. Improvements in satellite observations and computer models now provide three-day forecasts with higher accuracy than the one-day forecasts of 1980, but some of the most severe weather can still only be predicted a few minutes in advance.

Weather on Earth certainly can be intense and capricious. But how does it compare with weather on other planets in our solar system? Is our weather truly extreme? The answers to these questions can make Earth's atmospheric tantrums look downright placid, and they might even have implications for the evolution of life throughout the solar system.

Vacuum Cleaners of Dusty Mars

Mars has long been known for its nasty weather. When Mariner 9 arrived at Mars in 1971, a global dust storm raged across the planet and obscured almost the entire surface. Only a handful of peaks rose above the clouds, including Olympus Mons, the highest mountain in the solar system at an elevation of 27 km (17 miles) above Mars's average radius. Fortunately for our space probes, these planet-wide storms are relatively rare. Only eight have been recorded since 1956, the most recent in 2007.

It's really the smaller dust storms that rule the Red Planet. Dust devils (or traces of them) appear almost everywhere on Mars, from the deep Hellas Basin to the lofty Tharsis volcanic region. The Mars Orbiter Camera (MOC) aboard NASA's Mars Global Surveyor spacecraft detected nearly 11,500 active dust devils over four Martian years. The Spirit rover observed 533 dust devils in Gusev Crater during one season alone.

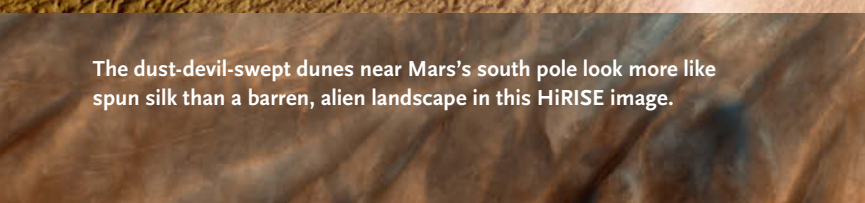
Shorter Martian vortices can be measured from lander images taken at the surface, but the tallest dust devils must be measured from above by orbiting spacecraft using shadow lengths and the angle of solar incidence. These observations show that "small" is a relative term: some dust devils can be more than a mile wide and reach higher than Mount Everest. Winds from these blowing behemoths travel the length of a football field in about a second.

Like tornadoes on Earth, these rotating giants leave their destructive mark on the Martian surface. As they sweep across the landscape, Mars's dust devils vacuum up a layer of red dust and expose the darker underlying substrate. Faster dust devils leave linear streaks, while slower vortices trace looping, curved paths. Dark tracks often remain visible for a month or longer, etching Mars with crisscrossed streaks.

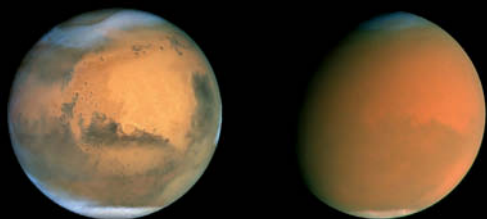
But similarities between tornadoes and dust devils end with their signatures on the landscape. The fundamental



Watch roving Martian dust devils and hear lighting on Saturn at skypub.com/planetstorm.



The dust-devil-swept dunes near Mars's south pole look more like spun silk than a barren, alien landscape in this HiRISE image.



Shown in natural color in these Hubble Space Telescope images, a global dust storm engulfed Mars in 2001 as the southern hemisphere's spring began. Only a few clouds appear in the left image, taken in June; by September, the storm had covered the planet for nearly two months.

dynamics of these whirling cousins are quite different. Tornadoes are strongly influenced by cold downdrafts that are enhanced by evaporative cooling behind the storm's core. These rear flank downdrafts wrap around the cyclone and squeeze rotating air into tighter rolls. In contrast, dust devils develop from a combination of warm updrafts and the uneven convergence of swirling horizontal winds (those pesky temperature gradients again).

Although tornadoes on Earth are relatively infrequent, Martian dust devils are remarkably commonplace. Based on the abundance of dark tracks on the Red Planet, many dust devils probably race across the barren surface every day. Yet because of the low atmospheric surface pressure on Mars, each dust devil individually packs a light punch — high winds but relatively small momentum. The winds are strong enough to lift dust particles (aided by the lower gravity of Mars, page 16), but an astronaut would barely feel them. Even a slight gust on Earth exerts more force.

The collective impact of these red whirling dervishes extends well beyond their local domain. Dust devils may contribute significantly to global atmospheric haze and the Martian dust cycle. Like clawing fingernails scraping away the skin of Mars, these incessant planetary vacuum cleaners are devilishly extreme.

Shocking Superbolts of Saturn

Bolts of lightning can be found sizzling throughout the solar system. All major planets with atmospheres (sorry, Mercury) show evidence of such electrical discharges. But nowhere does lightning crackle more powerfully than on the ringed giant Saturn.

Remarkably for such a common phenomenon, scientists don't fully understand how lightning forms. The leading hypothesis involves collisions of ice particles within a thunderstorm. As hail and softer snow pellets fall through the clouds, these large ice projectiles scavenge electrons from smaller ice crystals. The lower clouds become negatively charged, while the upper clouds swell with positively charged ice crystals. When roughly 100

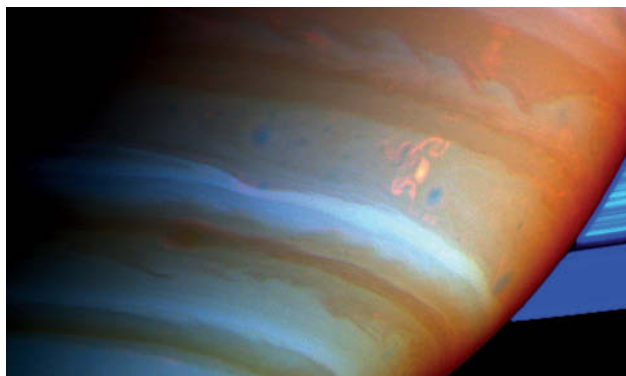
million volts build up in Earth's atmosphere, electrons discharge across the cloud (and sometimes to the ground) to paint dramatic displays of light and sound.

Because of water's electric dipole (the molecule is negatively charged on one side and positively charged on the other), water ice is particularly effective at stealing electrons. For this reason, planetary scientists usually focus on water clouds as the source of lightning. But these brilliant flashes of visible light are often hard to detect, especially on a planet's dayside or coming from water clouds buried deep within its atmosphere.

Luckily, lightning emits electromagnetic radiation at a variety of wavelengths. Radio waves in particular can travel great distances with minor attenuation. The ionosphere traps the low-frequency "whistler modes," named for their whistling sounds when heard over a radio receiver. Higher-frequency radio waves escape to space and sound like annoying static on an AM radio when intercepted by spacecraft instrumentation.

As NASA's Cassini spacecraft flew by Earth in 1999 for a gravitational assist on its way to Saturn, its Radio and Plasma Wave Science (RPWS) instrument detected radio bursts from lightning at a distance of 89,000 km above our home planet. The same instrument measured similar radio pulses at Saturn (called Saturn Electrostatic Discharges, or SEDs) much farther away, roughly 160 million km from the ringed planet. Since intensity drops off as the distance squared, Saturn's superbolts must be about a million times more energetic. Imagine for a moment what it must be like inside one of these superstorms — violent updrafts stronger than any on Earth, huge hailstones creating whopping charge separation, and epic lightning bolts perhaps as wide as the Washington Monument.

Until recently, most SEDs measured by Cassini originated from the southern hemisphere in a band at 35°



NASA / JPL / SPACE SCIENCE INSTITUTE

The Dragon Storm, with bizarre arms in Saturn's "Storm Alley," released shockingly strong radio emissions in September 2004, a product of intense electrical activity within the storm.

These dust-devil-streaked dunes near Mars's Antoniadi Crater in Syrtis Major Planum resemble waves.

Superrotating Tropical Titan

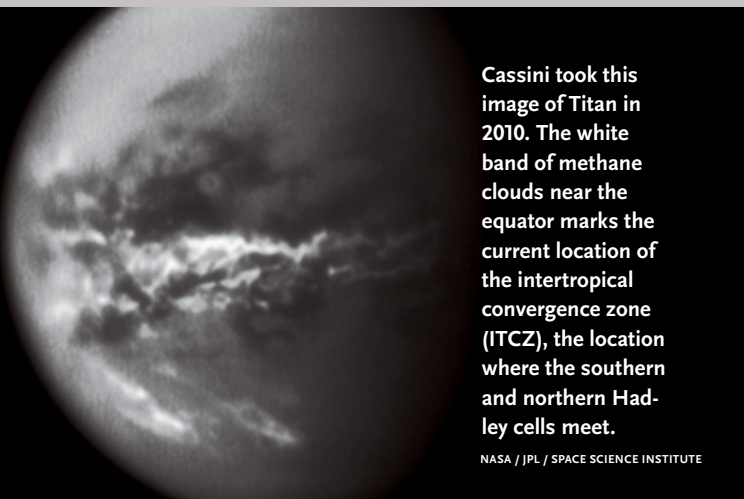
It may seem strange to call Saturn's largest moon "tropical." Titan receives only about 1% of the sunlight that reaches Earth, and its highest surface temperature is a bone-chilling -178°C (-288°F). But Titan's weather patterns closely resemble Earth's tropics and, perhaps even more so, those of blazing-hot Venus.

Titan is tidally locked to Saturn in a synchronous rotation of 15.9 days, meaning the same side of Titan always faces the ringed planet, just as the Moon always shows the same face to Earth. This relatively slow rotation makes Titan's atmosphere behave differently than the atmospheres of planetary bodies with short solar days. The dominant north-south circulation pattern on Titan consists of Hadley cells that extend from the latitude of maximum heating (e.g., the equator at equinox) all the way to the poles. For rapidly rotating planets, however, strong Coriolis forces prevent Hadley cells from reaching the poles. On Earth, Hadley cells only extend to $\pm 30^{\circ}$ latitude — a.k.a. the tropics.

Dynamic weather events at mid-latitudes on Earth, such as cyclonic low-pressure systems, undulating jet streams, and warm and cold fronts, are completely absent on Titan. Instead, the entire moon experiences weather characteristic of the terrestrial tropics (minus the hurricanes), including tranquil breezes and occasional methane showers.

But things are not calm everywhere on Titan. In the stratosphere, winds scream around the moon at over 100 meters per second (220 mph), rushing in the same direction as Titan rotates. Yet Titan's solid body only rotates at about 12 mps (26 mph). This prograde gusting means that Titan's atmosphere "superrotates," twirling completely around the moon in 1.9 days, roughly one-tenth the moon's synchronous rotation period. This extreme behavior is found on another slowly rotating body: Venus's atmosphere superrotates every 4 days compared to its solid-body rotation of 243 days.

The exact cause of superrotation on Titan and Venus remains unresolved. One leading hypothesis, supported by computer simulations, suggests that planet-scale atmospheric waves might transport significant amounts of momentum to the upper atmosphere, accelerating the winds to super-speeds.



Cassini took this image of Titan in 2010. The white band of methane clouds near the equator marks the current location of the intertropical convergence zone (ITCZ), the location where the southern and northern Hadley cells meet.

NASA / JPL / SPACE SCIENCE INSTITUTE

south latitude called Storm Alley. As the season transitions to northern spring, even stronger superstorms are brewing in the northern hemisphere. A massive "white" storm develops roughly every 30 years when Saturn's north pole tips toward the Sun. These "Great White Spots" (May issue, page 20) have been observed only six times since first being detected in 1876. But, as the sixth storm's 10-year-early arrival proved, Saturn's weather isn't so easy to predict. SEDs from this superstorm (which evolved into a giant, turbulent snake completely encircling Saturn) were so frequent that Cassini's RPWS instrument sometimes could not even resolve individual lightning strokes in the cacophony. The most shocking developments are surely yet to come.

Jupiter's Permanent Storm

Devastating hurricanes may roil for weeks on Earth. Electrifying storms on Saturn may blaze for months. But for longevity, Jupiter's Great Red Spot takes the prize.

Italian-French scientist Jean Dominique (Giovanni Domenico) Cassini, whose namesake spacecraft is now orbiting Saturn, first definitively observed this "permanent" spot in Jupiter's southern hemisphere in 1665. (Robert Hooke is often credited with discovering the Great Red Spot in 1664, but Hooke's "small spot" possibly occurred in the northern hemisphere and could have been a shadow transit of a satellite.) Observing records are sparse for the 165 years following Cassini's death in 1712, but the giant storm has been systematically recorded since 1878. This makes the Great Red Spot at least 134 and possibly 347 years of age, and perhaps even older.

The exact reason for the 165-year gap in documentation may never be known. It's possible that the spot Cassini saw dissipated and a different storm (the one we see today) developed more than a century later. Or maybe the blemish simply faded in color — Hubble Space Telescope images show variations from deep red to light salmon in the span of just a few years — and it could not have been detected with the telescopes of the 18th and 19th centuries.

Regardless of its exact age, the Great Red Spot is imposing. The anticyclonic high-pressure system towers 8 km over the surrounding cloud tops (nearly as high as Mount Everest). Winds whip around the giant whirlpool at 190 mps (425 mph), faster than any winds ever recorded on our home planet. Almost three Earths could fit inside the unrelenting maelstrom.

Why has this giant vortex lived for so long? First, intense internal heating from gravitational contraction fuels Jupiter's turbulent weather. The cloud tops receive 70% more energy from the planet's interior than from the Sun. Powerful thunderstorms (many of which have been detected



near the Great Red Spot) transport much of this heat from the deep interior to help equilibrate the energy imbalance.

Second, friction caused by land masses on Earth destroys hurricanes when they hit shore, limiting their lifetimes to a few weeks at most. Without a solid surface, Jupiter's interior exerts much less drag on the atmosphere. The end result is that Jovian storms can churn for years.

But the Great Red Spot isn't your typical low-friction Jovian storm. This vicious anticyclone is trapped between two high-speed jet streams, a westward jet to the north and an eastward jet to the south. Computer simulations show that multiple vortices, not just one, develop at the interface of such strong opposing jets. These vortices eventually consolidate into one big stable vortex. In other words, the Great Red Spot eats smaller spots to maintain its impressive physique.

Similar spots have been detected on the other giant planets — white spots on Saturn, white spots on Uranus (see page 54), and the Great Dark Spot on Neptune — but none of them seems to have the stamina of the Great Red Spot. Why such a long-lived vortex only on Jupiter? It's an intriguing puzzle, especially considering that Saturn also has strong internal heating and wicked jet streams.

Launched in August 2011 and set to arrive at Jupiter in 2016, NASA's Juno spacecraft will investigate the composition, structure, and dynamics of the Jovian atmosphere (S&T: September 2011 issue, page 18). A six-band microwave radiometer will penetrate the cloud tops to examine the deep atmosphere down to the 200-bar pressure level (about 400 km below the ammonia clouds). An infrared spectrometer will map deep water clouds and thunderstorm development. This important new mission may finally reveal the secrets of Jupiter's eternal storm.

Nature's Wrath or Nature's Nurture?

Mars, Saturn, and Jupiter all exhibit weather beyond the norm, with armadas of colossal dust devils, superbolts of shocking proportions, and a raging red tempest that may never die. For successful space exploration, *in situ* spacecraft must be built to investigate and withstand these types of extreme weather.

Weather is a critical consideration when design-

The Great Red Spot devours a smaller vortex in this sequence from 2008. Three red spots can be seen in these Hubble Space Telescope images: Great Red Spot, Little Red Spot (same latitude but to the west of the great one), and Red Spot Junior (south of the other two spots). In the last panel, the Little Red Spot (now on the east side) gets swallowed by its giant neighbor.

ing space missions. Scientists pored over images for evidence of dangerous dust devils when choosing the landing site near the north pole for NASA's 2008 Phoenix Mars Lander. Lightning on Saturn poses huge risks for electronics on future atmospheric probes, and the never-ending roller coaster ride of the Great Red Spot probably would shred a typical weather balloon. Human exploration in these violent conditions is almost unthinkable.

Brutal weather on other planets may make it difficult for any life form (as we know it) to survive. Consider a hypothetical microbe trying to get a flagellum-hold on Mars. Just when it gets attached to a nice piece of dust with some water ice nearby, *whoosh!* a dust devil mercilessly relocates it to a fatal locale. Nature's wrath may not be a microbe's friend.

On the other hand, extreme weather might encourage life. Hurricanes rejuvenate coral reefs, bring precipitation to drought-stricken areas, and flush out toxic pollutants from estuaries. Lightning in Earth's early atmosphere might even have sparked life by creating organic compounds such as amino acids. Maybe abnormal weather on other planets could prime their environments for life. We won't know until we look.

In terms of absolute wind speeds, vortex size, or electrical power, Earth may not have the wildest weather in our solar system. But for supporting life, there is nothing third-rate about the Third Rock. Earth's weather might just be the perfect storm. How wild is that? ♦

David Baker is chair of the Physics Department at Austin College in Sherman, Texas; Todd Rattcliff is a planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, California. Their recent book, The 50 Most Extreme Places in Our Solar System, explores some truly wild places. You can vote for your favorite at ExtremeSolarSystem.com.

On Mars, even fields of sand dunes built up inside craters bear the mark of passing dust devils.

Protoplanet Close-up



Jim Bell

Dawn is revealing the history of Vesta, a unique world that is part asteroid and part planet.

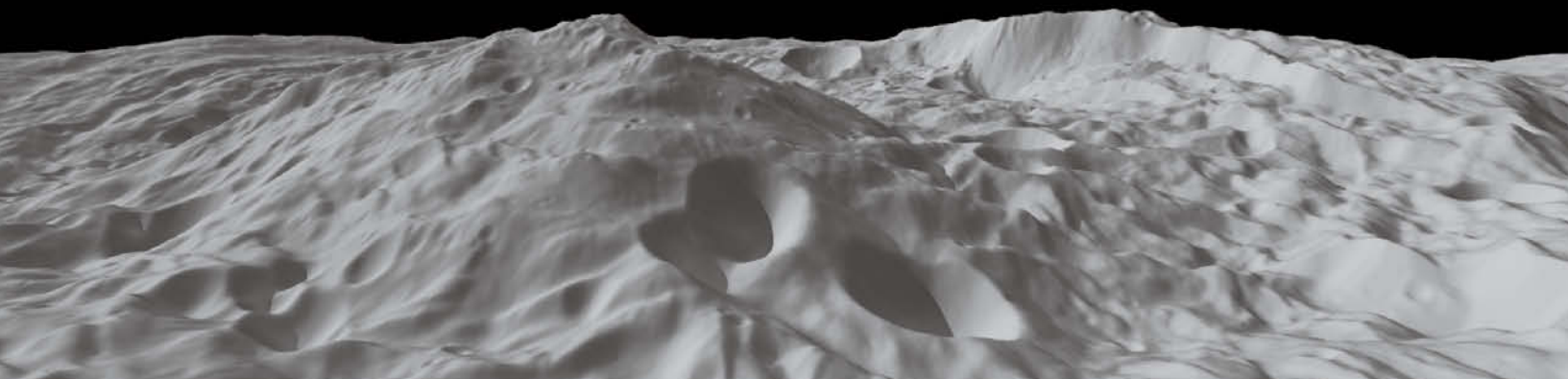
What is the recipe for building a planet? What kinds of building blocks are needed, and what forces hold them together or try to tear them apart? How does a planet's structure and composition change as it grows? What clues still preserved on planets or planetary fragments can help us understand their origins? These are the questions that NASA's Dawn mission was designed to answer.

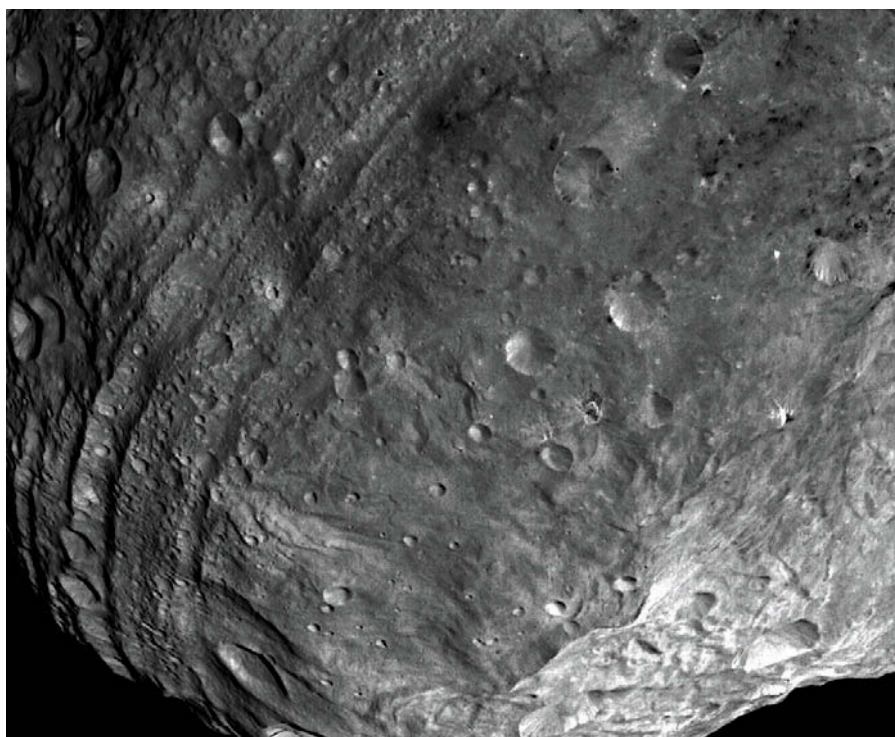
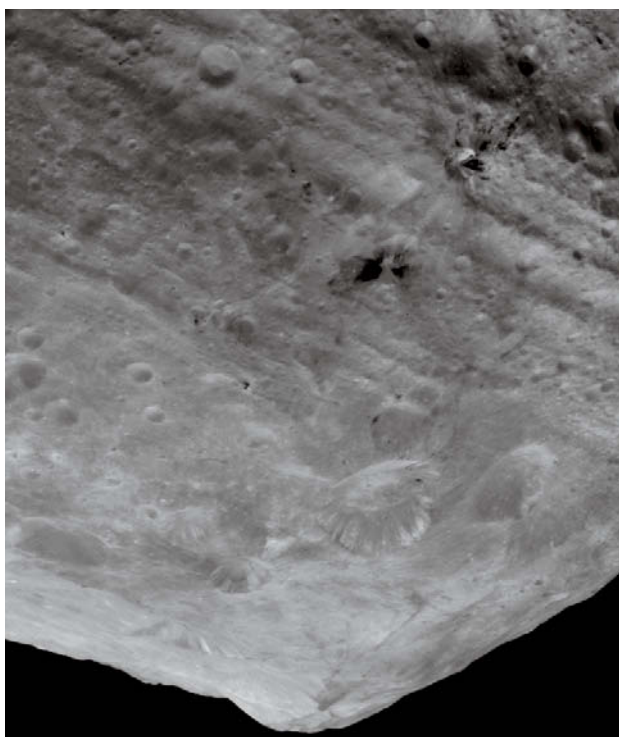
Dawn, the ninth mission in NASA's "faster, better, cheaper" Discovery series, is a spacecraft built to study two of the solar system's largest asteroids: Vesta and Ceres (*S&T*: November 2011, page 32). These two bodies alone represent a little over 40% of the mass of the main asteroid belt. Previous telescopic observations have hinted that rather than being primitive, unaltered objects like most smaller asteroids, Vesta and Ceres may be transitional protoplanets: part asteroid, part planet. If so, studying them up close could provide important clues about how planets such as Earth came to be.

Telescopic observations revealed Vesta to be dramatically different in color and surface mineral properties than any other large asteroid. Specifically, Vesta shows evidence of some of the kinds of basaltic minerals that we find in volcanic lava flows on Earth and other terrestrial planets. Scientists noticed that Vesta's infrared spectrum is remarkably similar to the spectra of a class of meteorites called the HEDs (Howardites,

Eucrites, and Diogenites), ancient samples of which apparently started out as volcanic rocks within the crust or mantle of a large terrestrial planet or protoplanet and that were later transported to Earth by impacts. More recently, astronomers have found many smaller asteroids with Vesta-like spectral properties (Vestoids) traveling as families of small bodies in orbits related to Vesta's. Hubble Space Telescope imaging revealed an enormous hole at Vesta's south pole — as if a large chunk of the asteroid had been blasted off in a giant impact.

Dawn was launched in September 2007, cruised past Mars in 2009 for a gravitational assist, and settled into orbit around Vesta in July 2011. The spacecraft's ion-propulsion system, and a cautious, systematic mission-operations approach, have enabled the Dawn science team to study the asteroid's surface from successively lower orbits. A high-resolution color camera has obtained thousands of images down to resolutions of less than 100 meters, and a visible to near-infrared spectrometer has acquired millions of spectra of the surface down to resolutions smaller than 1 kilometer. These images and spectra have enabled the Dawn science team to make some exciting discoveries about Vesta's geology and mineralogy. Tracking of the spacecraft's orbit has enabled accurate measurements of Vesta's mass as well as detailed estimates of its interior structure.





ALL IMAGES COURTESY NASA / JPL-CALTECH / UCLA / MPS / DLR / IDA UNLESS OTHERWISE CREDITED

Perhaps the most important finding is Dawn's discovery of not one but two enormous impact basins near Vesta's south pole. The largest, called Rheasilvia, is about 500 km (310 miles) across and nearly 20 km deep — more than enough volume to account for the HEDs and Vestoids. Rheasilvia has an enormous interior mound of rock nearly 200 km across and more than 20 km high, making it one of the solar system's highest mountains. We think it's the rebounded central peak created by the impact. Rheasilvia occurs on top of (and significantly overlapping) a slightly smaller (400-km-wide) basin called Veneneia. Using computer models of impact crater counts, scientists have estimated Rheasilvia's age as about 1 billion years and Veneneia's as about 2 billion years. The fact that they overlap near the south pole appears to be a cosmic coincidence. These two giant holes cause Vesta to appear distinctly flattened relative to a perfect sphere, as first noticed in HST images.

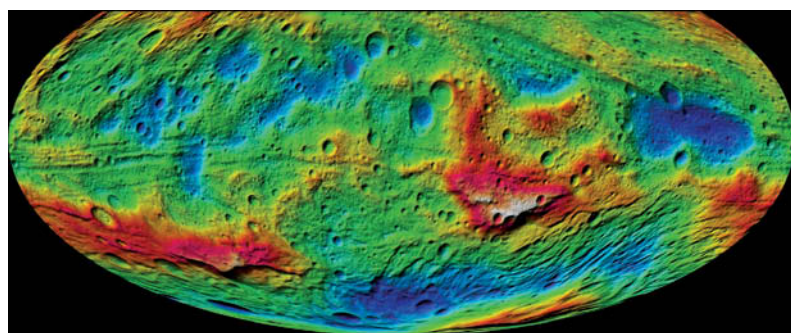
Indeed, impact craters dominate Vesta's shape and geology. Scientists have discovered five other basins larger than 150 km across, and thousands of smaller craters pockmark the surface. Vesta's surface is saturated with craters, meaning that the surface is so thoroughly covered by them that any new ones that form will wipe out

Above left: The south polar peak rises a whopping 15 km above the crater floor. **Above:** This image of Vesta's southern hemisphere highlights 10-km-wide equatorial grooves. The troughs are concentric to Vesta's two south polar impact basin and probably resulted from shock waves produced by the two giant collisions.

enough old ones to keep the total number about the same. The two large south polar impacts appear to have reset the geology of the southern hemisphere, which has fewer craters overall than the part of the northern hemisphere imaged so far. All of these impacts have created a shallow, well-mixed layer of fine-grained impact debris — a *regolith* — overlying the asteroid's dense bedrock subsurface. Vesta's regolith is similar in some ways to the powdery, impact-created upper surfaces found on other asteroids such as 433 Eros, as well as on the Moon.

Dawn has also revealed lots of evidence for erosion, mostly in the form of landslides and slumps of material

Left: This close-up of Vesta's south polar peak, with the asteroid's curvature removed, is based on a shape model. **Right:** A colorized terrain map of Vesta's surface illustrates the variety of topographical features. High areas are red and white, low ones are violet and blue. The equatorial grooves are easily visible.



NASA / JPL-CALTECH / R. JAUMANN (DLR) ET AL.

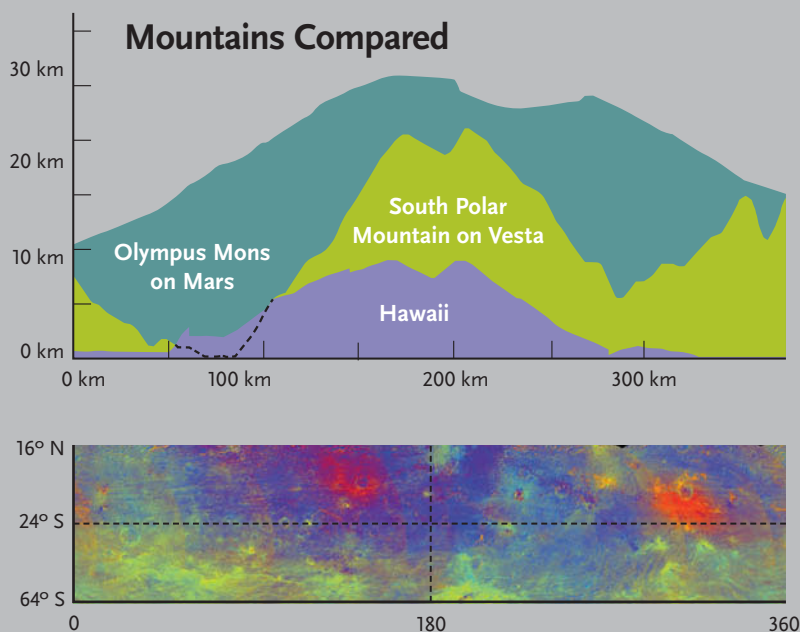


Rheasilvia, the larger south polar impact basin, dominates this view.

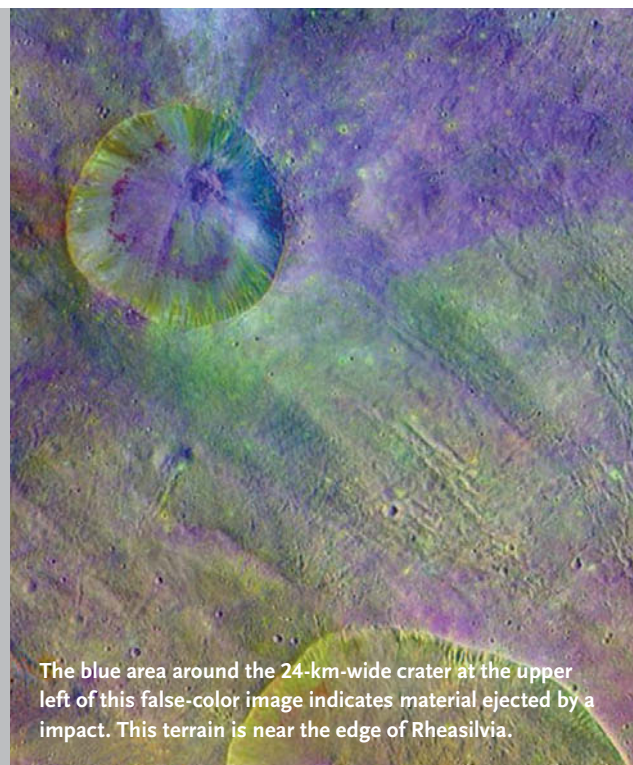
flowing down crater rims and walls due to Vesta's weak gravity (less than $\frac{1}{50}$ th of Earth's gravity). Dawn has also detected a series of long, deep grooves and troughs that circle much of Vesta's equator. Although scientists are still debating the details of how these tectonic features formed, they are clearly concentric to the two large south polar basins, and so they must be related. Perhaps the shock waves generated by these enormous impacts helped to form these giant cracks.

In addition to the geologic diversity, Vesta also exhibits the widest range of albedo (brightness), color, and infrared spectroscopic diversity of any asteroid yet encountered by a spacecraft. These variations indicate that Vesta is not a primitive world but instead that its surface materials have been processed by internal or external forces that can convert a planet's original inventory of rocks and minerals into other forms.

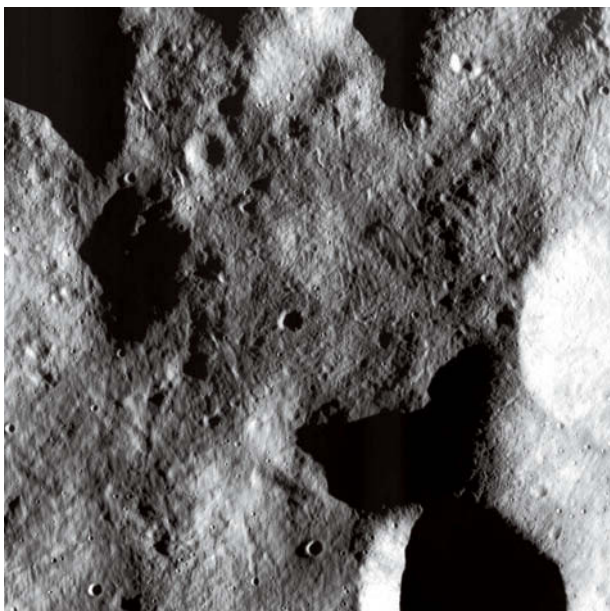
Indeed, a planet's mineral inventory provides information about the specific processes and environments that shaped that world. For Vesta, the composition consists of mixtures of basaltic volcanic minerals such as pyroxene — a common volcanic mineral on the terrestrial planets — as well as darker minerals whose types are more difficult to identify. The volcanic minerals match the compositions of the HED meteorites, which confirms the link between Vesta, the Vestoids, and this class of meteorite samples. The darker mineral phases could either be more iron-rich volcanic minerals, or perhaps more carbon-bearing materials from primitive (unprocessed) carbon-rich impactors that slammed into



Top: The central peak in Rheasilvia rivals Mars's Olympus Mons as one of the solar system's highest mountains. **Above:** Green areas in this false-color map of Vesta indicate high volcanic-mineral content. Redder and bluer areas highlight regions with the strongest color differences.



The blue area around the 24-km-wide crater at the upper left of this false-color image indicates material ejected by an impact. This terrain is near the edge of Rheasilvia.



This image from Vesta's largely unexplored northern hemisphere shows its surface etched with subtle grooves, some of which run for dozens of kilometers but are less than 1 km wide. Shifting regolith on Vesta's surface may be responsible for the grooves.

Vesta over time. If it's the latter, these may be the kinds of organic materials that helped seed the ingredients for life on Earth when delivered here by impacts.

Somewhat surprisingly given Vesta's mineral composition, Dawn has seen little or no evidence for lava flows, dikes, cones, domes, or other volcanic structures. Maybe these features once existed on Vesta, but they have since been destroyed by the onslaught of impact cratering. Or perhaps Vesta's volcanism has always been hidden below the surface.

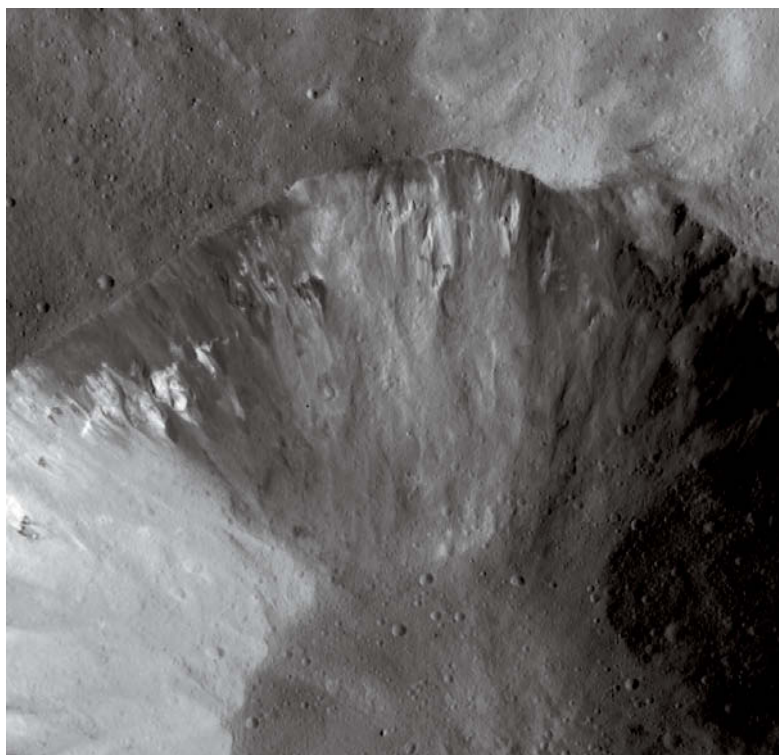
Looking at the bigger picture, the distribution of surface and impact-excavated minerals indicates that Vesta is a *differentiated* world. That is, the asteroid must have been at least partially melted early in its history, perhaps even with a melted ocean of magma floating at the surface. This enabled heavier iron- and nickel-bearing materials to sink and lighter silica- and oxygen-bearing materials to rise, segregating the interior into a core, mantle, and crust. Vesta's initial melting probably came from the combined heat of radioactive elements within the interior and the heat energy of innumerable impacts.

Differentiation into a core, mantle, and crust, and evidence for interior volcanic processes, are typical hallmarks of a terrestrial planet. Indeed, Dawn's measurements of Vesta's mass, combined with an

estimate of the asteroid's volume from stereo imaging data, indicate that it has a high rocky and metallic density of about 3.4 grams/cm³, comparable to the densities of the Moon and Mars. By some definitions, then, Vesta should be considered a planet, albeit a small one.

Some scientists think that Vesta may in fact be a protoplanet. In other words, Vesta may be the preserved remnant of a transitional class of planetary objects — it's no longer a primitive asteroid but it's not quite a classical terrestrial planet either. The world's meteorite collections reveal that we have samples from perhaps 100 or more such transitional protoplanets, including the parent body of the HEDs. Vesta is almost certainly that parent body, but it's the only object we know of in the solar system for which we can make that kind of claim. Vesta may thus be the last of its kind, a rare survivor of the violent era of planet formation.

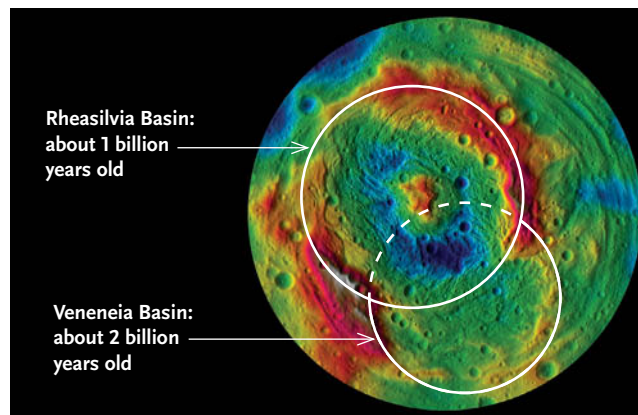
Dawn's mission at Vesta will continue through most of the summer of 2012. The science team will collect images and other data of Vesta's far northern hemisphere, which has been in winter darkness for most of the mission so far. Scientists are only now analyzing the compositional results from the gamma-ray and neutron spectrometer, since it took such a long time to build up the required signal levels during the mission's recent low-orbital-altitude phase. Will there be additional geological or mineralogical surprises in Vesta's more ancient northern hemisphere? Will the gamma-ray or neutron data reveal the presence of hydrogen-bearing materials (hydrated minerals or even ices) or other volatiles in the subsurface?



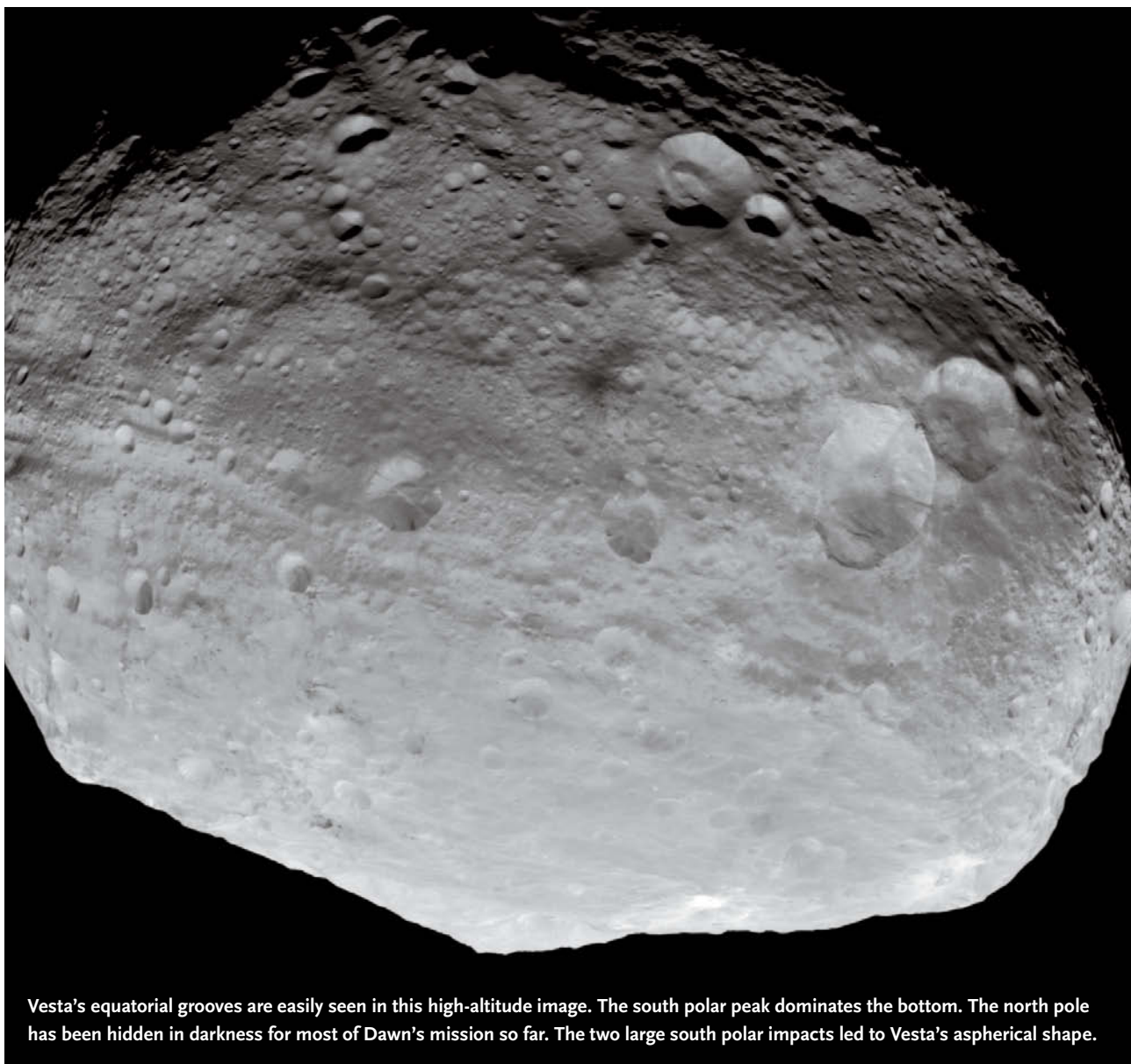
From an altitude of 272 km, Dawn examined a portion of this 40-km-wide crater that's located a few degrees south of the equator. The crater's sharp rim indicates a fairly recent impact, and its interior walls feature a variety of bright outcroppings.

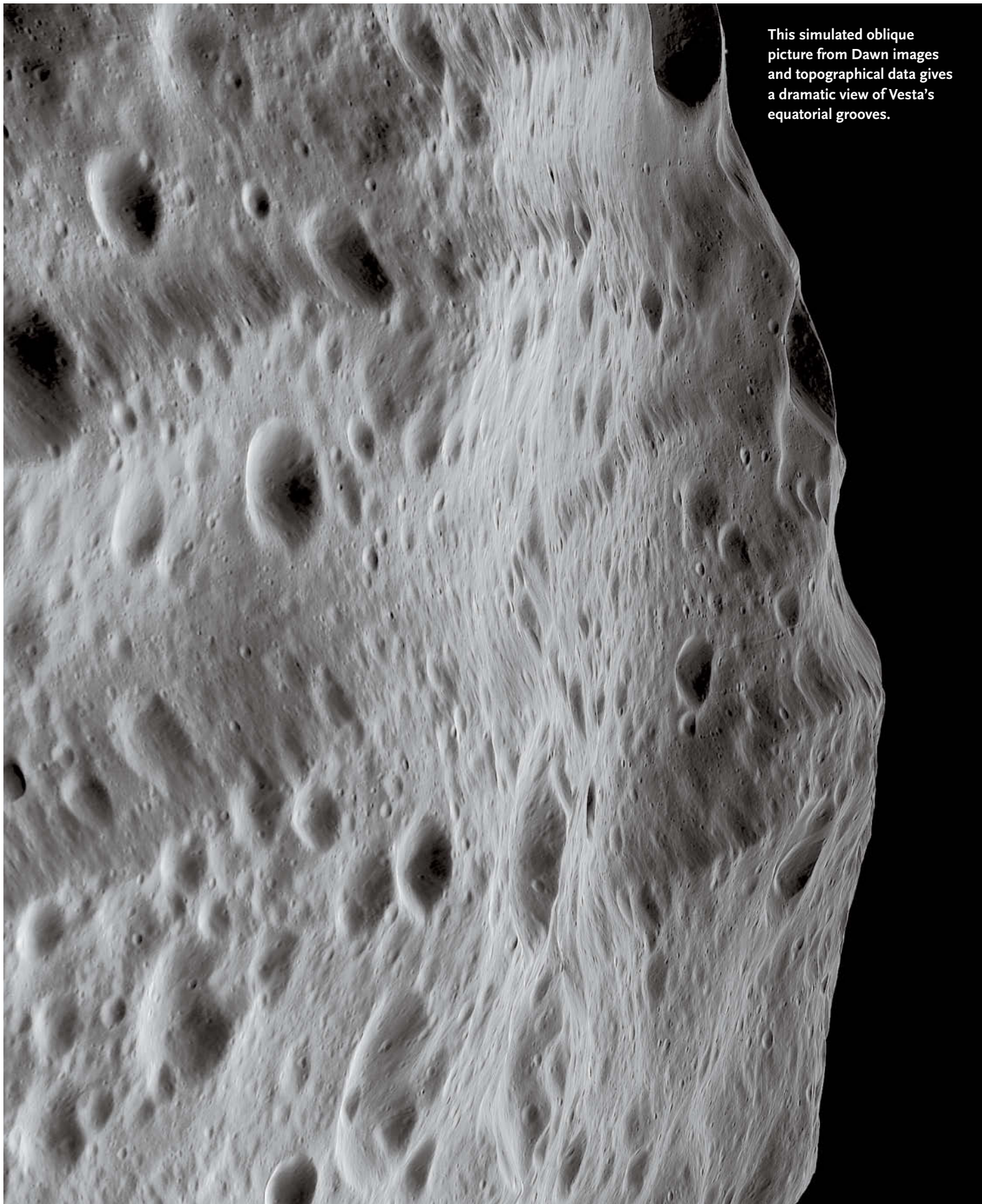
According to the current plan, in late August 2012, the spacecraft will be gently guided out of Vesta's orbit and on to its next encounter: a February 2015 orbital rendezvous with Ceres, the solar system's largest asteroid. Based on telescopic observations, Ceres is very different from Vesta, with a lower density and likely a more icy composition. What surprises await us there? Will Ceres prove to be a surviving protoplanet like Vesta, or something entirely different? I can't wait to find out! ♦

Contributing editor **Jim Bell** is a professor of astronomy and planetary science at Arizona State University. He was involved in the NEAR-Shoemaker mission to asteroid 433 Eros and is the lead scientist for the Mars Exploration Rover Pancam instruments. When not studying planetary surfaces, he roots for the Boston Red Sox and paddles Hawaiian outrigger canoes.



By counting craters, scientists can estimate the ages of the two giant impact basins around Vesta's south pole. As this false-color map shows, the two basins overlap — a cosmic coincidence.





This simulated oblique picture from Dawn images and topographical data gives a dramatic view of Vesta's equatorial grooves.

The 60Da: Canon's Astrophoto DSLR



U.S. price: \$1,499.95

www.usa.canon.com; available from dealers worldwide

www.usa.canon.com; available from dealers worldwide

Canon surprised the astronomy world with a version of its 60D camera designed specifically for astrophotography. How well does it work?

NO ONE EXPECTED THIS CAMERA. Even the Canon rumor sites on the internet were silent on its pending introduction. But last April Canon unveiled the 60Da, a version of its popular mid-range 60D designed specifically for astrophotography.

The 60Da follows in the tradition of the landmark Canon 20Da, an astronomical version of the 20D that could take excellent long-exposure images of the night sky. The Canon 20Da debuted in 2005 (I reviewed it in this magazine's November 2005 issue, page 84), but the camera was soon discontinued and not replaced until now.

The 60Da is aimed specifically at the astronomy market. Several years of DSLR improvement put it well ahead of the old 20Da. The 60Da has an 18-megapixel sensor in place of the 8-megapixel sensor of the 20Da, yielding much higher resolution. The 60Da has a modern, large,

articulated LCD screen. And the 60Da offers a variety of movie modes, including one ideal for shooting planets. DSLRs have come a long way since 2005.

The 60Da Advantage

The original 20Da had the first implementation of a feature now common on most DSLRs: live focus or “live view.” This allows focusing with a magnified view of a live image on the LCD screen, which is a far more accurate method than trying to focus using a dim optical viewfinder.

The feature that makes the 60Da unique is a special filter in front of the camera's sensor. All digital sensors

The Canon 60Da comes with the usual Canon accessories and cables, but it also includes the highly useful N3-to-E3 remote cable-release adapter, and an AC power supply. All photographs by the author.

are sensitive to infrared (IR) light that lenses typically can't bring to focus properly and they are thus fitted with IR-blocking filters. Unfortunately, the standard filters also block the red hydrogen-alpha (H-alpha) light of emission nebulae, which is important for astrophotography.

The 60Da still has an IR-blocking filter, but it is a special one that transmits a higher amount of visible H-alpha light. This is essential for anyone wanting to capture rich, colorful nebulae with a DSLR. Canon states that the 60Da's filter transmits three times the level of H-alpha light as the standard 60D and 1.5 times what the old 20Da transmitted.

I no longer own a 20Da to make comparisons, but I tested the 60Da against a Canon 7D (with the same 18-megapixel sensor as the 60Da) and a Canon 5D MkII that was modified for astronomical photography by Hutech Corporation (its IR-blocking filter was replaced with a Hutech Type 1b filter).

My overall conclusion is that the 60Da behaved similarly to the original 20Da — it recorded red nebulae with more depth and detail than did the 7D, but not as well as the Hutech-modified 5D MkII. On the other hand, the 60Da is factory warranted by Canon and offers nearly normal color balance for conventional "daytime" photography (something the modified camera doesn't do).

Color Balance

The number one question prospective buyers have had about the 60Da is whether it can take normal daytime photos. Many backyard astronomers looking for a DSLR want it to serve all purposes (making it easier to justify the



The camera's large, swing-out LCD screen provides neck- and back-saving convenience when framing, focusing, and reviewing images at the telescope.

expense). They are reluctant to spend \$1,500 or more on a camera dedicated solely for astro-imaging or whose images are compromised for anything other than glowing nebulae.

In the 60Da's instruction sheet, Canon warns in bold type that "...shooting normal subjects with this camera is not recommended." I found this statement to be far too conservative — the camera worked just fine for normal daytime shooting.

Changing the IR-blocking filter of a camera inevitably means compromising its color balance. My modified 5D MkII delivers daytime images that are very pink. Although this can be corrected in later processing (when shooting RAW images), the color balance never looks quite right.

With the 60Da's special IR-blocking filter, however, I

Shot in quick succession on a night with high clouds drifting through, these images (processed as identically as possible) are 4-minute exposures at f/2.8 and ISO 800. The 7D and 60Da images were taken with a 135-mm telephoto lens, while the larger sensor of the 5D MkII needed a 200-mm lens to capture a similar field of view.



Canon 7D — The off-the-shelf 7D does a respectable job of recording nebulosity, but red nebulae appear pale and more magenta than with the other cameras.



Canon 60Da — Red emission nebulosity records with a deeper red tint, and faint outlying bits of nebulosity missed by the 7D are picked up by the 60Da.



Hutech-modified Canon 5D MkII — This camera records the most nebulosity by far, though its images require much more color correction during processing.

These similarly processed images of the M8 region of Sagittarius are 90-second exposures at ISO 1600 taken in quick succession with the same lenses used for the accompanying North America Nebula set. They show sensitivity to red emission and blue reflection nebulae.



Canon 7D — The off-the-shelf 7D again does a good job, but does present red nebulae with a paler tone, and it barely records some of the faintest wisps of nebulosity.



Canon 60Da — The 60Da comes closer to matching the modified 5D MkII for tonal richness in this colorful area of sky. Emission nebulae are recorded as redder and more saturated than with the stock 7D.



Hutech-modified Canon 5D MkII — Subtle outlying bits of nebulosity east of the Lagoon Nebula and north of the blue Trifid Nebula record with more intensity than in the other cameras.

found that even without any post processing, daylight shots looked quite natural. Sunlit scenes might take on a slightly warmer tone, but nothing that's objectionable or even noticeable without a direct comparison. Sunset and twilight shots with the 60Da definitely looked redder, but to their advantage. The 60Da is thus more than a camera for just deep-sky imaging.

Noise Levels

As a rule with digital cameras, the smaller the pixels the higher the image noise, which becomes especially apparent in low-light pictures. Despite its relatively small 4.3-micron pixels, the 60Da, with its internal DIGIC IV processing, delivered images with low noise. Shots taken with my trio of test cameras showed that the 60Da had slightly lower noise than the Canon 7D, but not as low as the hallmark Canon 5D MkII, with its larger, 6.4-micron pixels. The difference between the 60Da and 5D MkII in RAW images appeared to be about one *f*/stop. For example, noise in 60Da shots taken at ISO 1600 looked similar to the noise in 5D MkII shots taken at ISO 3200.

In previous testing (before I sold my

much-loved Canon 20Da cameras), I found that the 5D MkII and 20Da had similar levels of noise and definitely set the standard for DSLRs. The 60Da comes within an *f*-stop of that standard, a fair trade-off for the 60Da's increased resolution from its smaller pixels. Any residual noise is easily smoothed out with image-processing software. Although the 60Da can be set to as high as ISO 12,800, I found images at that setting too noisy to be useful for anything more than finding and framing deep-sky targets.

In room-temperature tests, 8-minute, high-ISO exposures taken with the lens capped (to record nothing but black) showed uniform neutral backgrounds with no sign of the edge glows, color shifts, or serious banding exhibited by some other DSLR cameras I've tested. This is performance absolutely critical to any DSLR camera intended for astro-imaging.

Movie Modes

The 60Da offers a choice of movie modes, including 1,920 × 1,080 HD at 30 frames per second. These are useful for fast-changing sky phenomena and for tours around the Moon. A mode that the 60Da

shares with the 60D (but lacking in Canon's higher-end cameras) is Movie Crop, which records a movie from the sensor's central 640 × 480 pixels at 1:1 resolution (the pixels are not binned or downsampled as they are in other movie modes).

Although the field of view and frame size are small in Movie Crop mode, they are sufficient to record close-ups of the Moon and planets, thus turning the 60Da into a 60 frame-per-second planetary cam-



The 60Da's Movie Crop mode turns the DSLR into a high-resolution planetary camera that records 60 frames per second at 1:1 pixel resolution. This daytime Venus image from last June 9th is a single frame grabbed from a movie taken with a 130-mm *f*/6 refractor and 2x Barlow.

era. Coupling the 60Da's 4.3-micron pixels to a telescope with a focal length of 2,000 mm yields an image scale of 0.4 arcsecond per pixel, ideal for planetary imaging.

The convenience of Movie Crop mode is that the movie is recorded directly to the camera's SD memory card, without the need for an external computer. (Jerry Lodriguss wrote more about this type of planetary imaging in last May's issue, page 72.) This mode extends the utility of the 60Da (and 60D) to shooting planets, a subject up to now far from ideal for DSLR cameras.

Other Features

Having used Canon's hefty 5D MkII and 7D cameras for several years, I was pleasantly surprised at the compactness and light weight of the 60Da. At 675 grams (24 ounces), this is a camera that won't burden small telescopes on light mounts.

A wonderful feature introduced with the 60D is an articulated LCD screen. Having spent many nights crouching and peering up at a DSLR's screen to focus and frame a target, I found the swing-out screen of the 60Da to be a godsend. If only because of its convenience, I found myself using the 60Da for all kinds of sky shooting. It soon became my favorite camera.

Unique to the 60Da is the inclusion of an adapter cable that allows Canon's optional TC-80N3 interval timer to connect to the camera. Like the lower-cost Canon Rebel cameras, the 60Da uses a small E3 jack for its remote controls. But Canon's upper-end cameras have a proprietary N3 jack. The 60Da's adapter cable allows the use of these

N3 accessories. This is a real plus for those of us loyal to Canon's TC-80N3 timer, which enables the user to set up a series of shots that are triggered automatically.

The 60Da uses Canon's LP-E6 battery, the same as in the higher-end Canon 7D and 5D MkII/MkIII cameras. In addition, the 60Da comes with Canon's ACK-E6 power supply, which allows the camera to operate off AC power. This is noteworthy since the ACK-E6 is a \$150 optional accessory with other Canon cameras.

Any Caveats?

If there is any concern with the 60Da, it is how long it might remain on the market. The 20Da lasted barely a year before it was discontinued. The non-astronomical 60D was released in mid-2010, ages ago in DSLR years. Will it be replaced soon with a 70D sporting more features and will there be a corresponding astronomical version?

On the other hand, as astrophotographers, we don't need many of the latest features offered by new cameras, such as multi-point autofocus, rapid-fire continuous shooting, or touchscreen controls. And for the most part we do not need more megapixels, certainly not at the cost of noise — the paramount concern of astrophotographers.

What would be nice is lower noise at higher ISO settings, allowing us to grab clean images in ever-shorter exposure times, perhaps without guiding or even tracking the sky. The Canon 60Da is certainly capable of excellent high-ISO performance, and it offers all the features

most astrophotographers will need for many years of shooting. Furthermore, Canon assures us that any future firmware updates issued for the Canon 60D will also work on the 60Da.

A feature I was hoping for in the 60Da is one offered only in the 5D series — the ability to buffer up to five images in the camera and then take a single dark frame that's applied to all of them. This speeds up deep-sky shooting immensely. As it is, for those of us who prefer to use "real-time" dark frames, the 60Da requires us to alternate light and dark frames, doubling the time it takes to acquire a set of images.

At a suggested retail price of \$1,500, the Canon 60Da carries about a \$500 premium over the street price of a 60D. But this increase is mitigated somewhat by the worthwhile accessories included with the 60Da. A modified 60D purchased from a third party costs upwards of \$1,400, but it won't include the accessories, and, as mentioned earlier, will be compromised for daytime photography.

With all that in mind, the Canon 60Da is a great deal. There is certainly no question in my mind that the 60Da is the best choice for anyone wanting a DSLR for all types of astrophotography, as well as for daytime use. Many thanks go to Canon for serving our astronomy market. ♦

Sky & Telescope contributing editor **Alan Dyer** has been using DSLRs for astrophotography since 2004. Galleries of his images are at www.amazingsky.photoshelter.com and at his photo blog www.amazingsky.net.

As explained in the text, the 60Da is a respectable camera for daytime photography without the addition of special filters or major color correction during image processing.



Canon 7D — The stock 7D set on Auto White Balance provides the expected color balance with blue sky, green grass, and neutral grays on the weathered farm buildings.



Canon 60Da — Set for a Auto White Balance (center frame), the 60Da is close to the 7D but with a slightly redder tint (the grass is not as green, the buildings are a warmer tone). Switching to a Custom White Balance (right), which is explained in the camera manual, helps compensate for the warmer tone, producing a daylight shot with better overall color balance.



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Sky & Telescope, the essential magazine of astronomy, has produced a beautiful and extremely accurate new globe of the Moon. Unlike previous Moon globes based on artistic renderings, this new globe is a mosaic of digital photos taken in high resolution by NASA's Lunar Reconnaissance Orbiter under consistent illumination conditions. The globe shows the Moon's surface in glorious detail, and how the nearside actually appears when viewed through a telescope. It also shows the farside in equal detail. The globe includes 850 labels that identify major basins (maria), craters, mountain ranges, valleys, and the landing sites of all the Apollo missions and robotic lunar landers.



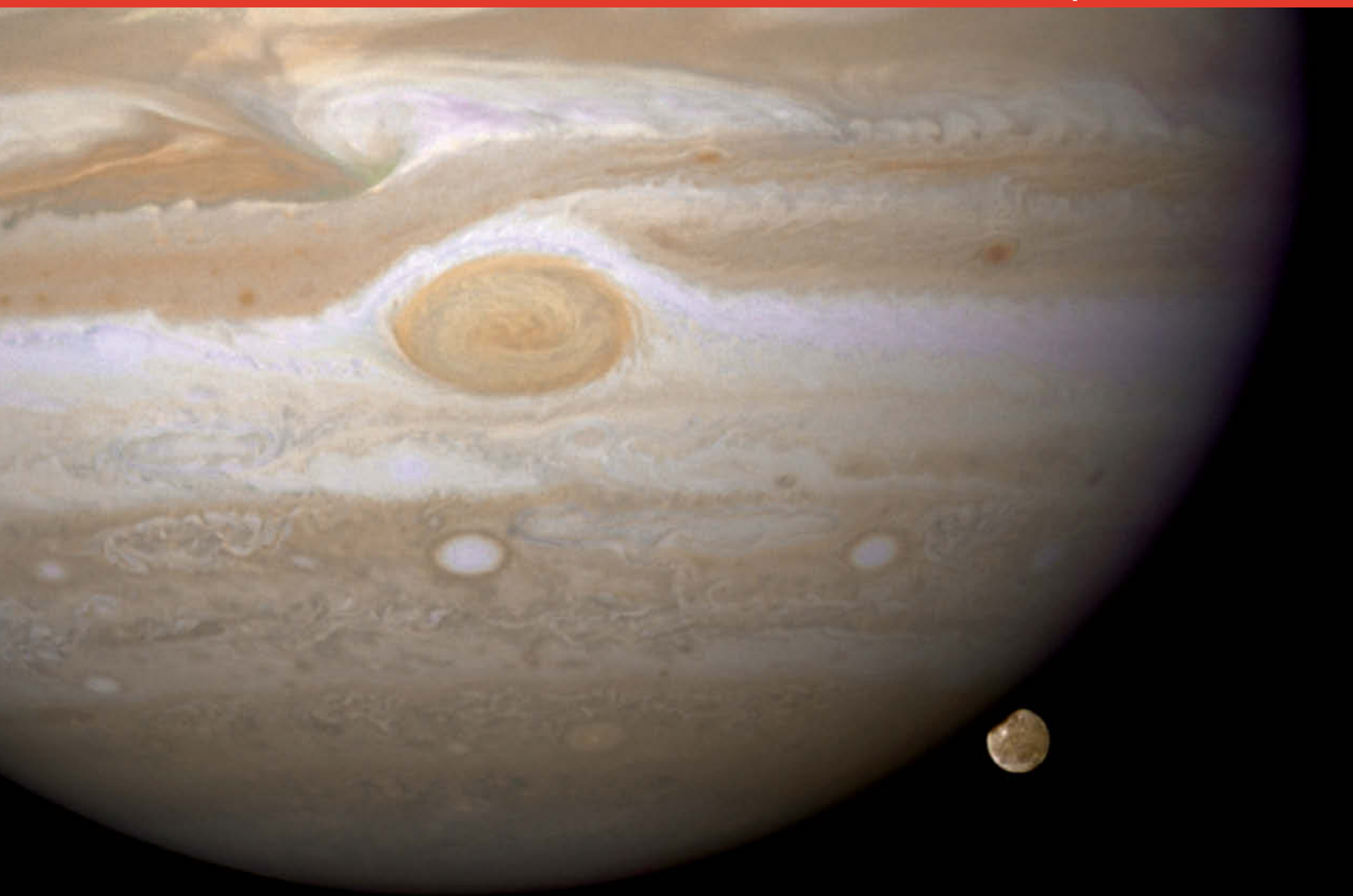
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Planets Fly Low at Dusk and High at Dawn

The Hubble Space Telescope caught Ganymede, Jupiter's largest moon, disappearing behind the planet in April 2007.

PHOTOGRAPH:
NASA / ESA / Erich Karkoschka / University of Arizona

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OBSERVING Sky at a Glance

SEPTEMBER 2012

- 8 DAWN:** Jupiter is about 1° above the 3rd-quarter Moon for North Americans; see page 48.
- 12 DAWN:** Venus is left of the waning crescent Moon.
- 13–14 EVENING OR NIGHT:** Algol is at minimum brightness for roughly 2 hours centered on 10:02 p.m. on the 13th PDT (1:02 a.m. on the 14th EDT); see page 51.
- 14 DAWN:** A very thin crescent Moon should be visible low in the east starting about an hour before sunrise. Look lower right of 1st-magnitude Regulus.
- 14–28 DAWN:** The zodiacal light is visible in the east 120 to 80 minutes before sunrise from dark locations at mid-northern latitudes. Look for a tall, broad, rightward-leaning pyramid of light with Venus directly on its axis.
- 16 EVENING:** Algol is at minimum brightness for roughly 2 hours centered on 9:51 p.m. EDT.
- 18, 19 DUSK:** Low in the west-southwest, the waxing crescent Moon is well to Saturn's left on September 18th and close to the left of Mars on the 19th; see page 48.
- 22 AUTUMN BEGINS** in the Northern Hemisphere at the equinox, 10:49 a.m. EDT.
- 22, 23 ALL NIGHT:** Binoculars and telescopes show that Uranus is extremely close to the almost identically bright star 44 Piscium; see page 50.
- 28–29 ALL NIGHT:** Uranus is at opposition to the Sun, rising around sunset, soaring highest in the middle of the night, and setting around sunrise.

Planet Visibility

	◀ SUNSET		MIDNIGHT		SUNRISE ▶	
Mercury	Hidden in the Sun's glow all month.					
Venus					NE	E
Mars	SW	W				
Jupiter				NE	S	
Saturn	W					

PLANET VISIBILITY SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

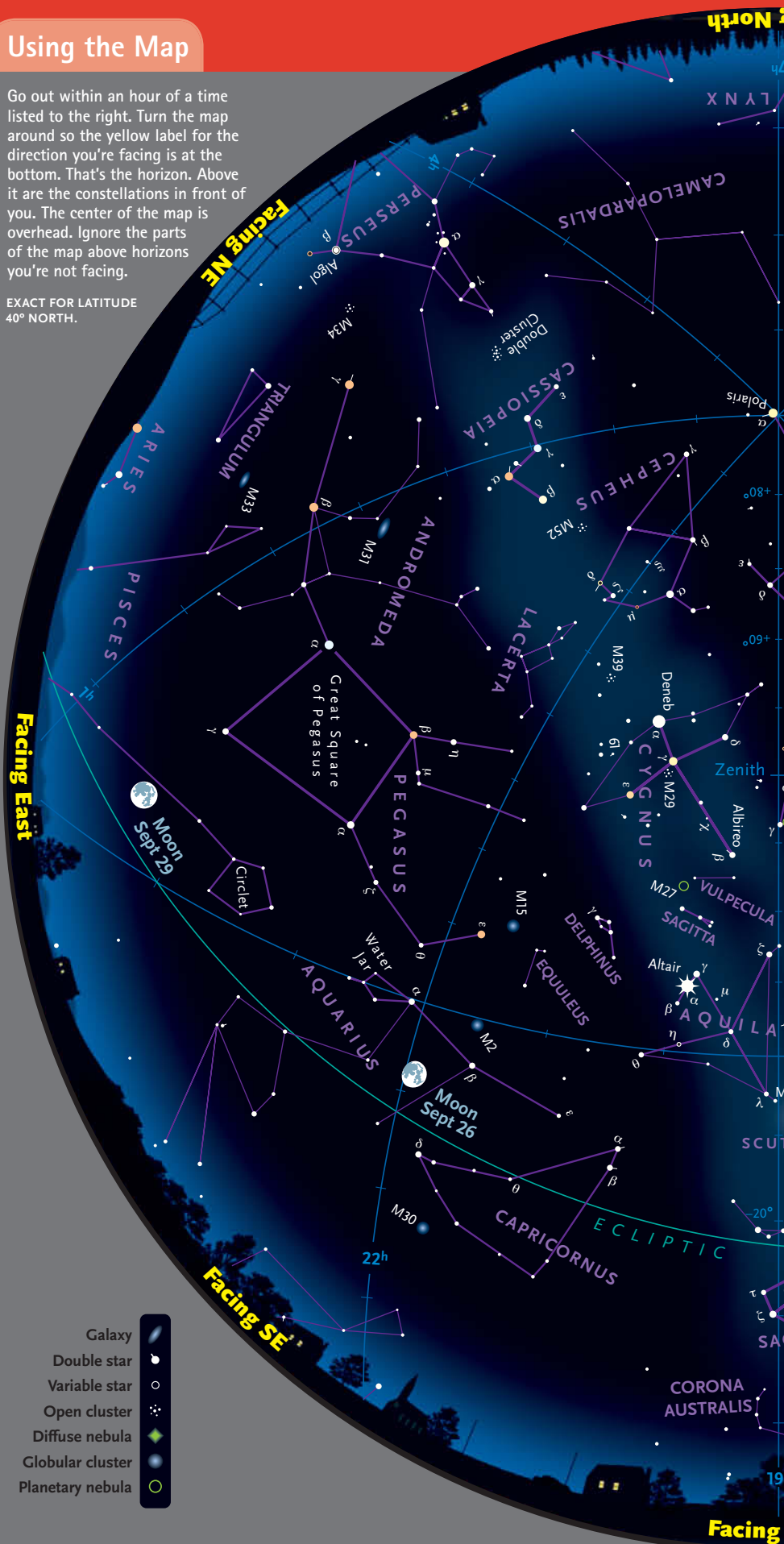
Moon Phases

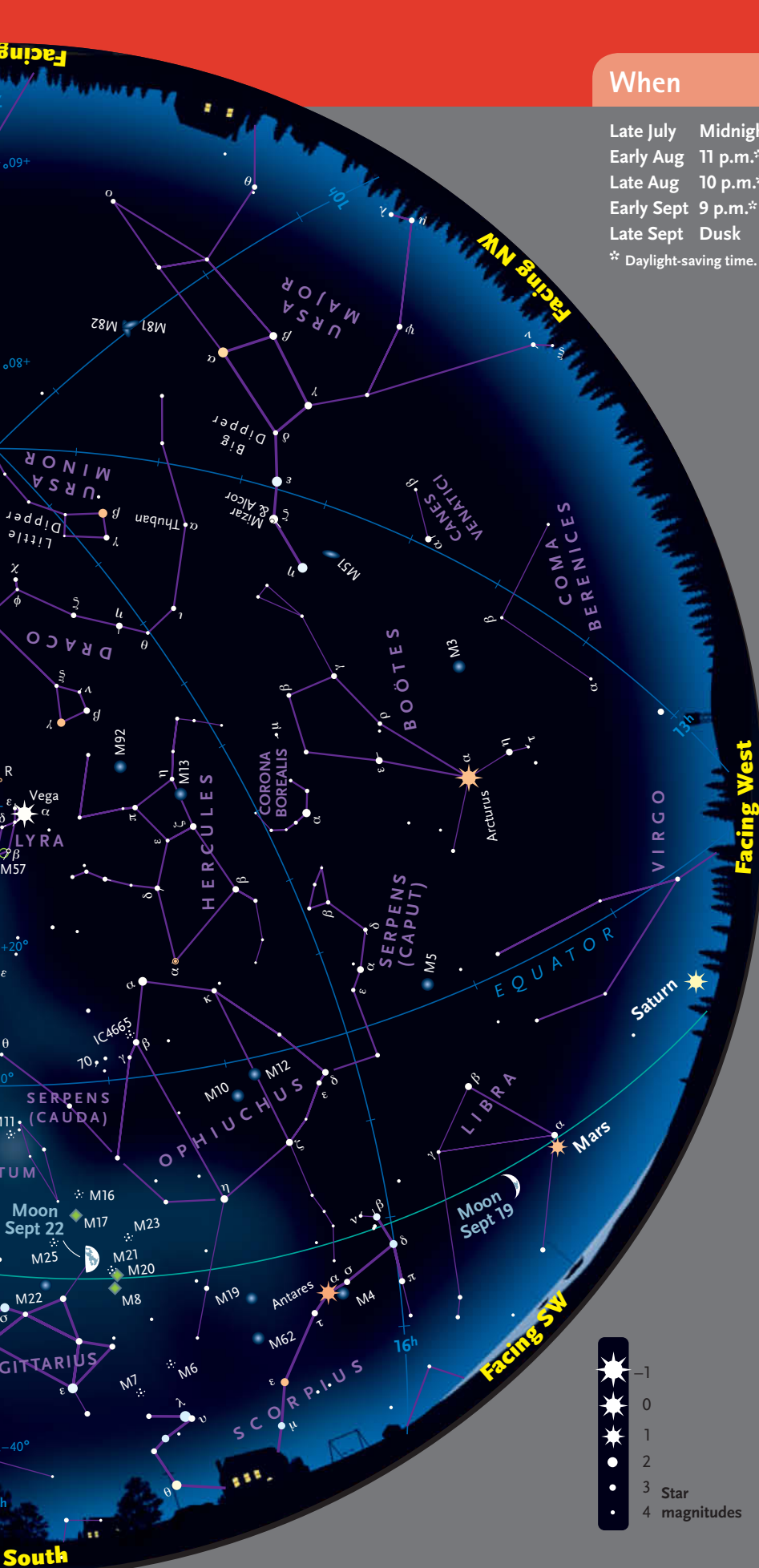
SUN	MON	TUE	WED	THU	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

Using the Map

Go out within an hour of a time listed to the right. Turn the map around so the yellow label for the direction you're facing is at the bottom. That's the horizon. Above it are the constellations in front of you. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing.

EXACT FOR LATITUDE 40° NORTH.





When

Late July	Midnight*
Early Aug	11 p.m.*
Late Aug	10 p.m.*
Early Sept	9 p.m.*
Late Sept	Dusk
* Daylight-saving time.	

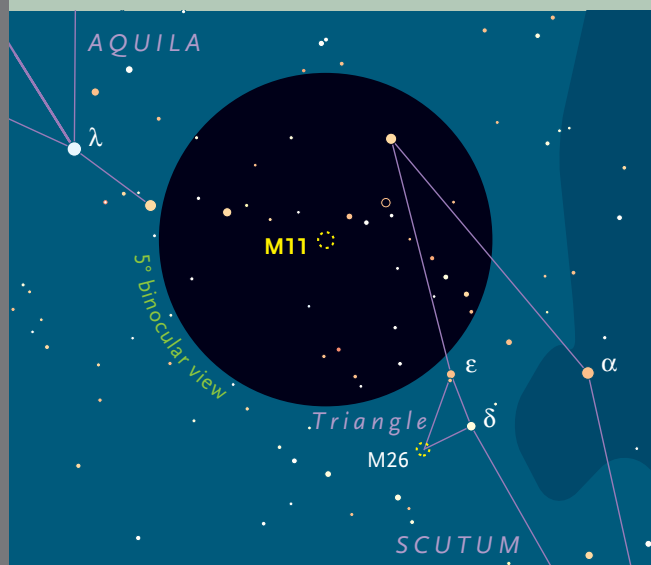
Binocular Highlight

Scutum Odd Couple

Despite its modest size, Scutum is a binocular wonderland rich with intriguing Milky Way fields and home to a pair of Messier clusters. And to borrow the setup of an old joke, one cluster is among the most pleasing and rich in the sky — and the other is M26.

M11 and **M26** make an interesting open cluster odd couple. Let's begin with the more eye-catching of the two: M11, otherwise known as the Wild Duck Cluster. This grouping got its distinctive name from Admiral W. H. Smyth who, in his 19th-century guidebook, likened its appearance to "a flight of wild ducks" (see page 53). Listed as a 5.8-magnitude object, M11 is a snap to sweep up in any pair of binoculars. In my 10×50s, I see a single, lead duck situated near the southeast corner of a little hazy cloud of unresolved starlight. Beyond the southeast edge of the cluster lies another star — a sort of stray duck. What I find intriguing is that the stray shines at magnitude 9.1, while the lead duck is 8.6, yet the former actually appears brighter to me. Does it look that way to you too? Perhaps some kind of contrast effect is in play here.

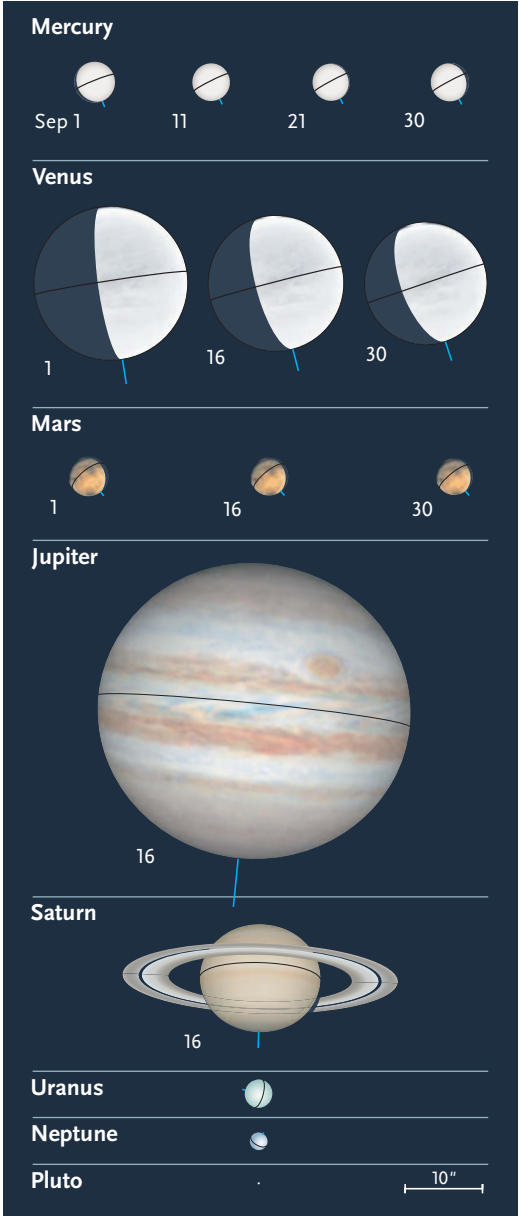
As bright and easy as M11 is, M26 is dim and difficult. Indeed, this 8th-magnitude object holds the distinction of being the most elusive open cluster in the Messier catalog. Luckily, its position is easy to pin down — M26 completes a right triangle with the nearby 5th-magnitude stars Epsilon (ε) and Delta (δ) Scuti. In my 10×30 image-stabilized binoculars, the cluster looks like a slightly soft, 8th-magnitude dot. My 10×50s reveal a single 9.2-magnitude star embedded within M26, giving the cluster the appearance of a miniature, mirror-reverse version of neighboring M11. ♦ — Gary Seronik



Watch a SPECIAL VIDEO



To watch a video tutorial on how to use the big sky map on the left, hosted by S&T senior editor Alan MacRobert, visit SkyandTelescope.com/maptutorial.

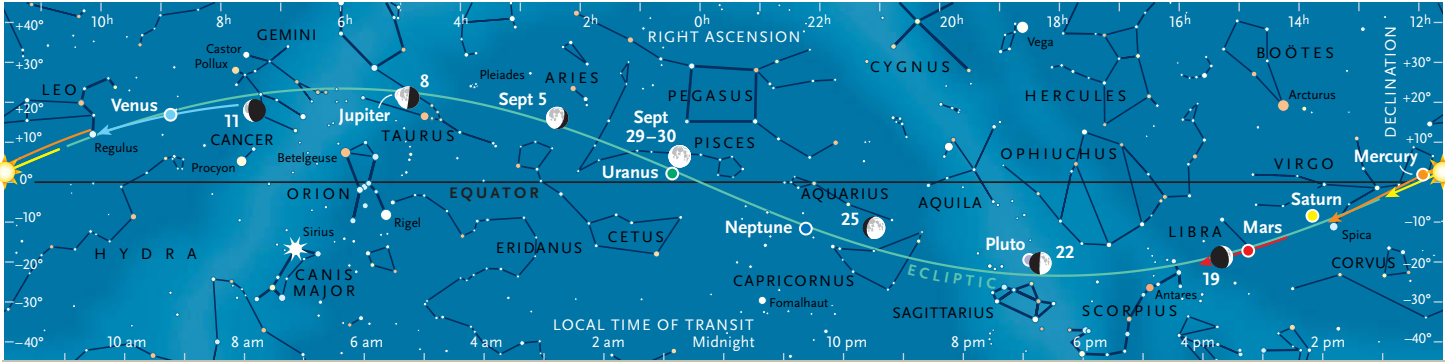


Sun and Planets, September 2012

	Sept	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	10 ^h 41.6 ^m	+8° 16′	—	−26.8	31′ 42″	—	1.009
	30	12 ^h 25.9 ^m	−2° 48′	—	−26.8	31′ 57″	—	1.001
Mercury	1	10 ^h 09.3 ^m	+13° 10′	9° Mo	−1.4	5.3″	93%	1.273
	11	11 ^h 21.8 ^m	+5° 52′	2° Ev	−1.8	4.9″	100%	1.379
	21	12 ^h 26.3 ^m	−2° 00′	9° Ev	−0.9	4.8″	97%	1.392
	30	13 ^h 19.2 ^m	−8° 38′	14° Ev	−0.4	5.0″	92%	1.353
Venus	1	7 ^h 41.3 ^m	+19° 21′	45° Mo	−4.3	19.9″	58%	0.836
	11	8 ^h 26.5 ^m	+17° 55′	44° Mo	−4.2	18.3″	63%	0.912
	21	9 ^h 12.2 ^m	+15° 40′	43° Mo	−4.2	16.9″	67%	0.985
	30	9 ^h 53.2 ^m	+12° 59′	41° Mo	−4.1	15.9″	70%	1.049
Mars	1	14 ^h 11.0 ^m	−13° 45′	56° Ev	+1.2	5.2″	91%	1.803
	16	14 ^h 50.1 ^m	−17° 03′	52° Ev	+1.2	5.0″	92%	1.876
	30	15 ^h 29.0 ^m	−19° 46′	48° Ev	+1.2	4.8″	93%	1.937
Jupiter	1	4 ^h 52.7 ^m	+21° 44′	84° Mo	−2.3	39.2″	99%	5.025
	30	5 ^h 00.3 ^m	+21° 54′	111° Mo	−2.5	42.9″	99%	4.591
Saturn	1	13 ^h 40.1 ^m	−7° 55′	47° Ev	+0.8	16.0″	100%	10.416
	30	13 ^h 51.6 ^m	−9° 04′	22° Ev	+0.7	15.6″	100%	10.688
Uranus	16	0 ^h 26.5 ^m	+2° 03′	166° Mo	+5.7	3.7″	100%	19.085
Neptune	16	22 ^h 12.9 ^m	−11° 43′	158° Ev	+7.8	2.3″	100%	29.062
Pluto	16	18 ^h 28.7 ^m	−19° 38′	103° Ev	+14.1	0.1″	100%	32.052

The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial diameter.) Last are the percentage of a planet's disk illuminated by the Sun and the distance from Earth in astronomical units. (Based on the mean Earth–Sun distance, 1 a.u. is 149,597,871 kilometers, or 92,955,807 international miles.) For other dates, see SkyandTelescope.com/almanac.

Planet disks at left have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.





The Celestial Dolphin

This tiny but shapely constellation is full of wonder.

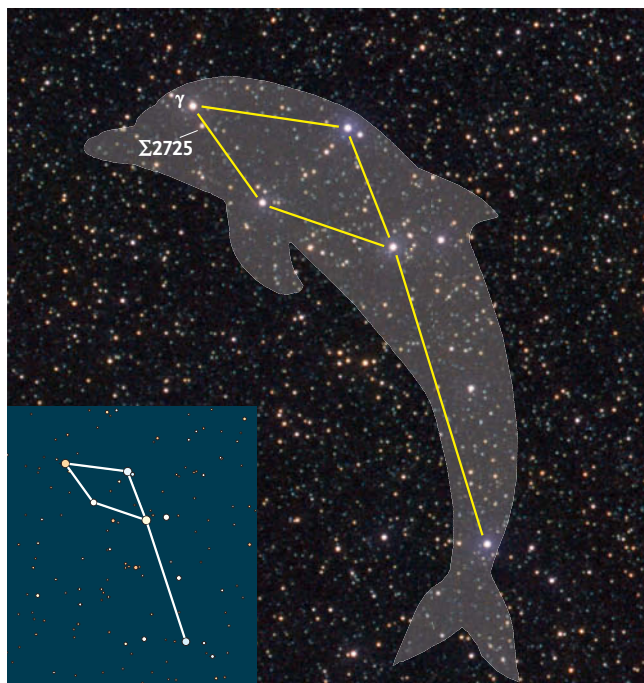
For the past two months in this column we toured entire classes of celestial objects, objects scattered far and wide across the summer sky. This month I want to concentrate on a tiny part of the September evening sky: the minute pattern of Delphinus the Dolphin. We will find that despite its relatively few stars, this little constellation has a surprisingly large amount of legend, lore, and observational interest.

Delphinus in context. Delphinus is charming partly due to the way it fits into the larger scene of the summer sky. Its attractive position in the big picture is undeniable — just outside the region enclosed by the Summer Triangle, which contains the even smaller pattern of Delphinus's neighboring constellation Sagitta the Arrow. But Sagitta is fairly dim, requiring a rather dark sky to appreciate properly. Delphinus is much brighter — easy to spot with the naked eye on a clear night in a small city or suburb.

Delphinus also lies against a darker natural background than Sagitta because it's just outside the main band of the summer Milky Way. The Milky Way is often imagined to be a river, so maybe this is a fresh-water dolphin. Or perhaps it's leaping out of the celestial sea that spills out of Aquarius's Water Jug — a region whose watery constellations now flood most of the southeast sky.

The head of Pegasus (which includes 2nd-magnitude Enif, the Nose) also points to Delphinus. Even more interestingly, Delphinus lies along two lines of wonderful sights for binoculars and telescopes. One consists of increasingly small star patterns: little Delphinus, smaller Sagitta, and smallest Brocchi's Cluster (better known to amazed binocular and telescope users as the Coathanger). The other line runs from the Ring Nebula (M57) through the great color-contrast double star Albireo and the Dumbbell Nebula (M27).

Delphinus's best deep-sky object. The diamond of Delphinus includes its own telescopic gem, whose beauty is detectable in small telescopes. I'm referring to Gamma (γ) Delphini, which marks the nose of the Dolphin. Its 4.5- and 5.5-magnitude components are separated by 10", and its colors are usually held to be gold and green. Can you see the emerald tint of the secondary? Just 15' to the southwest is James Mullaney's "Ghost Double" — Struve 2725 ($\Sigma 2725$), whose 6"-wide pair of 7.6- and 8.4-magnitude stars is like a ghost image of much brighter Gamma.



Delphinus in legend and lore. The pattern of Delphinus, a diamond with a tail, really does suggest a dolphin. The most famous dolphin in Greek mythology, and the one most often associated with this constellation, is the one that saved the poet Arion when he leaped into the sea to escape being murdered by the piratical crew of the boat he was sailing on. In the middle of the 20th century, research began to hint that dolphins might be even more intelligent than previously thought, possessing brains that are extraordinarily complex, and also quite large for animals of their size. So it isn't surprising that the first group of scientists gathered to discuss searching for extra-terrestrial intelligence — a group that included astronomers Frank Drake and Carl Sagan — decided to call itself the Order of the Dolphin.

There's a final amusing piece of lore about Delphinus. Let me give you a hint. It involves an astronomer called Nick Hunter. Never heard of him? You can find him in many histories of astronomy but not under quite that name. How many of you know who he was? I'll identify him and his marvelous connection to Delphinus here next month. ♦

Planets Fly Low at Dusk and High

Venus and Jupiter dominate the predawn sky.

At dusk in September, Mars and Saturn glimmer low in the southwest to west-southwest. Dim Uranus is visible all night long and has a very special conjunction.

Brilliant Jupiter rises in the late evening and shines at its highest in the south by dawn. Even-brighter Venus comes up long before the Sun and is about 1/3 the way up the eastern sky by morning twilight.

But the most impressive solar system events to observe in the Americas this month may be three impressive Moon-planet conjunctions.

DUSK

Mars and **Saturn** both start September a little more than 10° high in the west-southwest at mid-twilight for skywatchers at mid-northern latitudes. Look for them well to the lower left of brighter Arcturus. The two planets are 10° apart in eastern Virgo on September 1st (Saturn is the one on the right), but by month's end Mars has moved all the way into Libra, leaving Saturn far behind.

Mars nearly keeps pace with the Sun in its eastward motion against the stars, setting about 2 hours after sunset for all the rest of this year! Saturn, on the other hand,

is on the way out. It's very low in bright twilight by the end of September and will soon be lost from view. Spica, 5° or 6° below Saturn, is probably too low to spot by late September. Mars shines at magnitude +1.2 all September, Saturn around +0.8.

Use binoculars on September 14–16 to find the wide double star Alpha Librae (Zubenelgenubi) about 1° from Mars. The star's 2.7- and 5.2-magnitude components are almost 4' apart, making them an easy split in binoculars.

Mercury is too close to the Sun all month to observe without a telescope.

EVENING TO DAWN

Uranus is at opposition on the night of September 28–29, so it rises around sunset and is highest in the middle of the night. Uranus shines at magnitude 5.7 all September, bright enough to see with the naked eye in very dark clear skies. Its bluish (some see greenish) disk appears 3.7" wide in a telescope. Finder charts for Uranus and Neptune are on page 50. They show that Uranus retrogrades from north-western Cetus into Pisces this month. What's really exciting is that on the American evenings of September 22nd and 23rd,

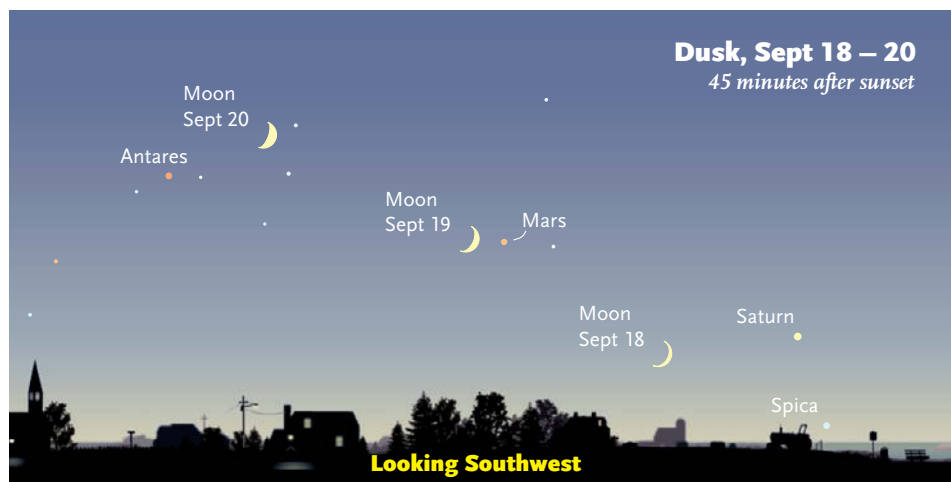
Uranus lies little more than 1' from almost identically bright 44 Piscium.

Neptune is two magnitudes dimmer than Uranus and, in Aquarius, crosses the meridian more than two hours earlier.

Pluto is more than eight magnitudes dimmer than Uranus and is highest in the early evening; see page 52 of the June issue for a finder chart.

Jupiter rises a little before midnight (daylight-saving time) as September opens, and around 10 p.m. as the month closes. The enormous planet brightens from –2.3 to –2.5 and grows from 39" to 43" wide this month. Jupiter is more than 2/3 of the way up the southern sky when it transits the meridian around dawn.

Jupiter is at quadrature (90° west of the Sun) on September 7th, so this is the month when the planet and its Galilean satellites cast their shadows farthest to the



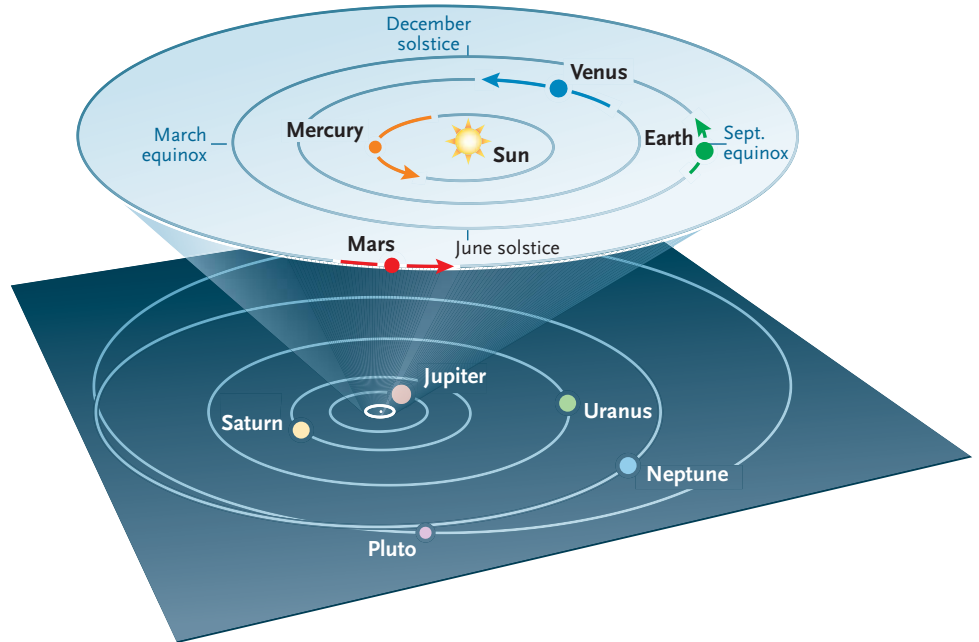


at Dawn

side. Jupiter's eastward motion away from Aldebaran is slowing and will soon reverse.

Venus has yet another superb month for viewers at mid-northern latitudes. We see it rise about 3½ hours before the Sun all month, shining at magnitude -4.2 about 1/3 of the way up the eastern sky by the middle of morning twilight. Venus now is past greatest elongation, so its phase is more than half lit, and its apparent diameter shrinks from 20" to 16" during September.

But the planet speeds across much scenic starry background this month. On September 6th, Venus is in line with Castor and Pollux (though $10\frac{1}{2}^\circ$ from Pollux). On September 12th and 13th Venus passes about $2\frac{1}{2}^\circ$ south of M44, the Beehive Star Cluster — though the crescent Moon nearby interferes with the naked-eye view. On September 14th Venus is a little more than 1° from Delta Cancr (Asellus Austr-



lis). On September 23rd Venus crosses into Leo, ending the month just 3° upper right of Regulus — which it will meet in a shockingly close conjunction on October 3rd.

MOON AND SUN

The **Moon** is almost precisely at last quarter at dawn on September 8th, when North

ORBITS OF THE PLANETS

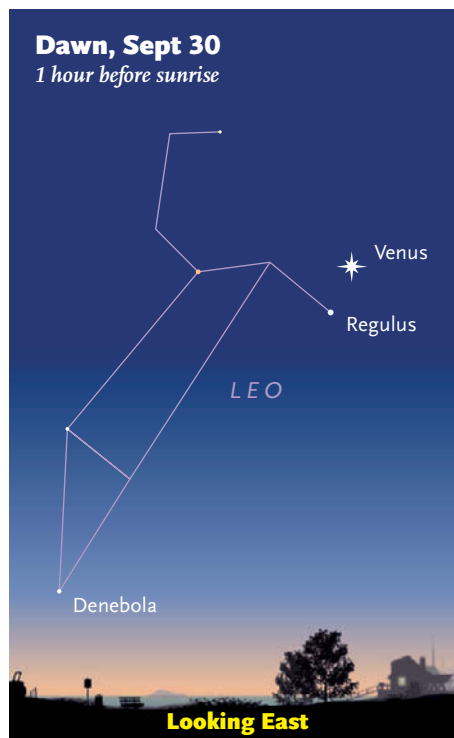
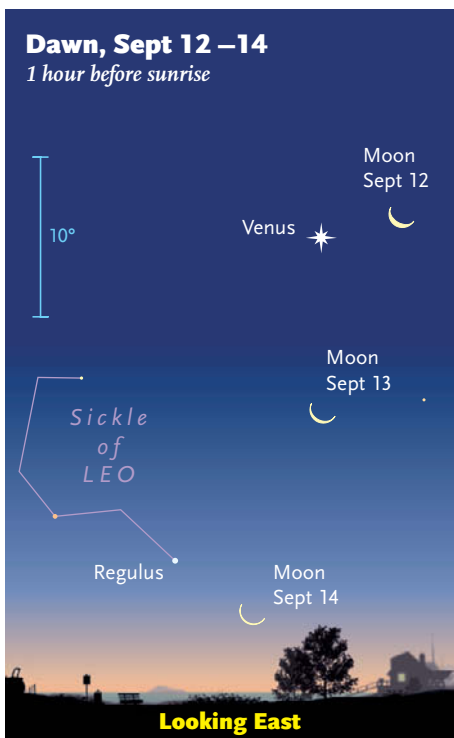
The curved arrows show each planet's movement during September. The outer planets don't change position enough in a month to notice at this scale.

Americans see bright Jupiter perched dramatically close just above it. The Moon occults Jupiter shortly after daybreak on the 8th for most of South America.

The waning lunar crescent is not far to the right of Venus on September 12th, and the waxing crescent is very close to Mars's left at dusk on September 19th. The Moon occults Mars shortly before or after sunset on the 19th for much of South America.

The Sun reaches the September equinox at 10:49 a.m. EDT on September 22nd, starting autumn in the North Hemisphere and spring in the Southern Hemisphere. The Harvest Moon — the full Moon closest to the autumn equinox — occurs this year on the American evening of September 29th. ♦

These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west); European observers should move each Moon symbol a quarter of the way toward the one for the previous date. In the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist at arm's length. For clarity, the Moon is shown three times its actual apparent size.



Spotting Uranus and Neptune

The twin ice giants have taken on more cosmic importance than we expected.

Anyone with binoculars can spot the two outermost major planets: Uranus easily at magnitude 5.7, Neptune with more difficulty at 7.8. Almost any telescope at fairly high power will show them to be, if not exactly distinct balls, at least nonstellar in appearance; they're 3.7 and 2.3 arcseconds wide this season.

Uranus and Neptune are currently south of the Great Square of Pegasus, near the Circlet of Pisces and under the elbow of Aquarius respectively. They're well up by late evening in August and September. The finder charts below show their positions among the stars for the rest of this observing season. The large chart is all you may need for Uranus; it shows stars to as faint as magnitude 6.5. The small black boxes there show the areas covered by the

The near-twin outermost planets creep westward for the next few months, then double back on themselves. The black boxes below show the areas of the deeper charts at right.

close-ups on the right, where stars are plotted to magnitude 9.5.

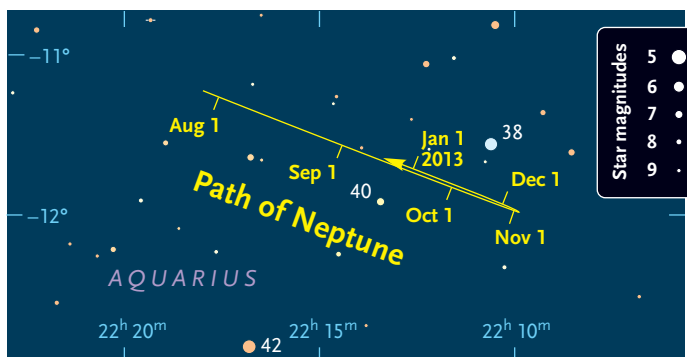
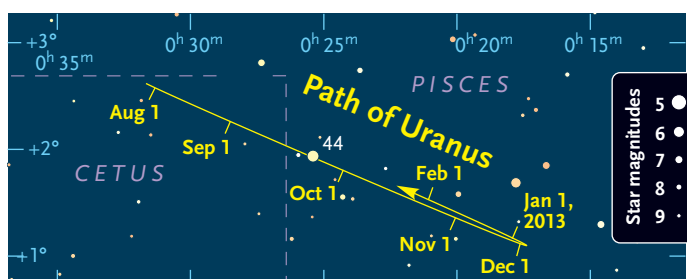
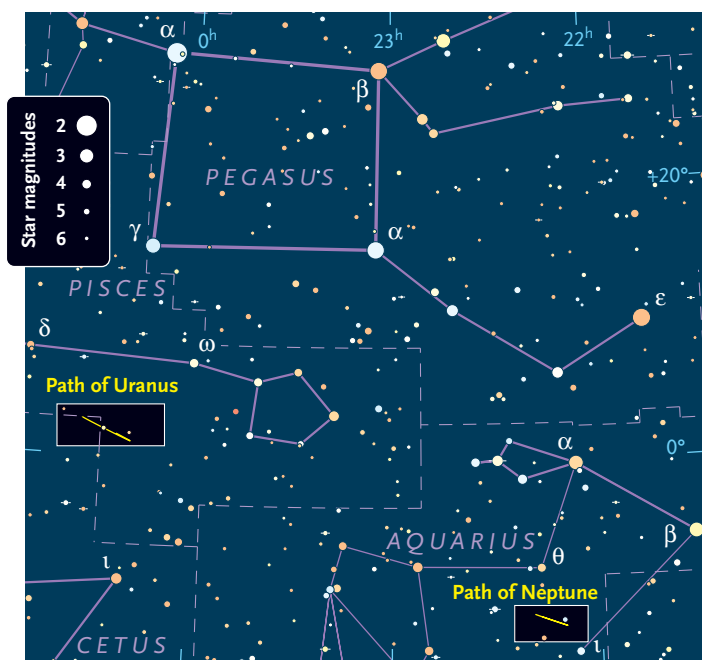
Uranus appulse. Set your calendar to remind you to look at Uranus on the evenings of September 21st through 23rd. It will be passing close by the almost identically bright star 44 Piscium. They'll be about 3.3 arcminutes apart on the American evening of the 21st, 1.0' on the 22nd, and 1.7' on the 23rd. (Their closest approach, or *appulse*, is 0.7' around 12^h September 23rd UT, good viewing for Australia.) Look for subtle color contrast between the yellow star, spectral type G5 III, and slightly aquamarine-gray Uranus.

Uranus comes to opposition on September 29th. Neptune was at opposition on August 24th. The story of how Uranus's rotation period was determined visually by an amateur (in fact a former *S&T* editor) is told in the article that begins on page 54.

Neptunes everywhere. Only recently have astronomers realized the wider sig-

nificance of Uranus and Neptune in the universe at large. Rather than being unique oddballs as we used to think of them (with 14.5 and 17.1 Earth masses, respectively), they've turned out to be the most common type of planet in the universe discovered so far. Of the 2,321 likely extrasolar planets that NASA's Kepler project has announced to date, "Neptunes" (broadly defined) amount to 1,118, whereas Jupiters and super-Jupiters add up to only 281.

Super-Earths, with 2 to 10 Earth masses, put in an impressive showing with 676 candidates, and these likely outnumber Neptunes in reality considering that small planets are harder to detect. Smaller Earth analogs may be even more abundant; Kepler has logged 246 candidates with less than 1.25 Earth diameters. Theorists expect the trend of "the smaller the more" to continue on down, but the statistics for small, hard-to-detect planets are still fairly weak. For the moment, Uranus-Neptune analogs rule.





Action at Jupiter

After lighting the morning sky all summer, Jupiter rises in mid-evening in September (in Taurus) and shines moderately well up in the east by midnight or 1 a.m. daylight-saving time.

Even the smallest scope shows Jupiter's four large Galilean moons. Binoculars usually show at least two or three of them. Identify them with the diagram on the next page. Also listed there are all their interactions with Jupiter's disk and shadow during September, events fascinating to watch.

And here are the times, in Universal Time, when Jupiter's Great Red Spot should cross the planet's central meridian, the imaginary line down the center of Jupiter from pole to pole. The dates (also in UT) are in bold. Eastern Daylight Time is UT minus 4 hours; Pacific Daylight Time is UT minus 7 hours. The Red Spot appears closer to Jupiter's central meridian than to the limb for 50 minutes before and after these times:

September 1, 9:51, 19:47; **2**, 5:43, 15:38; **3**, 1:34, 11:30, 21:25; **4**, 7:21, 17:17; **5**, 3:12, 13:08, 23:04; **6**, 9:00, 18:55; **7**, 4:51, 14:47;

8, 0:42, 10:38, 20:34; **9**, 6:29, 16:25; **10**, 2:21, 12:16, 22:12; **11**, 8:08, 18:03; **12**, 3:59, 13:55, 23:50; **13**, 9:46, 19:42; **14**, 5:37, 15:33; **15**, 1:29, 11:24, 21:20; **16**, 7:16, 17:11; **17**, 3:07, 13:03, 22:58; **18**, 8:54, 18:50; **19**, 4:45, 14:41; **20**, 0:37, 10:32, 20:28; **21**, 6:24, 16:19; **22**, 2:15, 12:11, 22:06; **23**, 8:02, 17:58; **24**, 3:53, 13:49, 23:45; **25**, 9:40, 19:36; **26**, 5:32, 15:27; **27**, 1:23, 11:18, 21:14; **28**, 7:10, 17:05; **29**, 3:01, 12:57, 22:52; **30**, 8:48, 18:44.

These times assume that the spot is centered at System II longitude 184°. If it has moved elsewhere, it will transit $1\frac{2}{3}$ minutes late for every 1° of longitude greater than 184°, or $1\frac{2}{3}$ minutes early for every 1° less than 184°.

Markings on Jupiter appear a little more contrasty through a blue or green filter. The larger your scope, the darker the blue or green can be; you want enough light to see details clearly, but not so much that you lose visual details to glare.

Try several magnifications to find the one that shows the most in the current seeing conditions. And keep looking. More and more details come out with protracted scrutiny.



Algol, the prototype eclipsing variable star, fades from its usual magnitude 2.1 to 3.4 and back every 2.87 days. It stays near minimum light for two hours, and it takes several additional hours to fade and to rebrighten. Shown above are magnitudes of comparison stars (with the decimal points omitted). The "21" star is the bright foot of Andromeda.

These geocentric time predictions (times as seen from the moving Earth) are from the heliocentric (Sun-centered) elements $\text{Min.} = \text{JD } 2452253.559 + 2.867362E$, where E is any integer. Courtesy Gerry Samolyk (AAVSO).

Minima of Algol

Aug.	UT	Sept.	UT
2	4:53	2	17:48
5	1:41	5	14:36
7	22:30	8	11:25
10	19:19	11	8:14
13	16:07	14	5:02
16	12:56	17	1:51
19	9:45	19	22:40
22	6:33	22	19:28
25	3:22	25	16:17
28	0:11	28	13:06
30	20:59		

Unusual Occultations

September brings four occultations that are unusual in various ways and challenging in different ways.

- The naked-eye star Alpha² Librae, magnitude 2.7, will be occulted for up to 2.6 seconds by the faint asteroid 363 Padua on September 16th along a path from Washington state to Florida — in the daytime! If the blue sky is especially clear and clean you *might* be able to see the star in a telescope, especially at high power, if you can get aimed exactly right. Alpha² is the brighter star of the wide Alpha Librae pair. But can you hold it in continuous view well enough to tell an occultation from an atmospheric shimmer or an eye twitch? Some observers will surely try. For details see the link below.

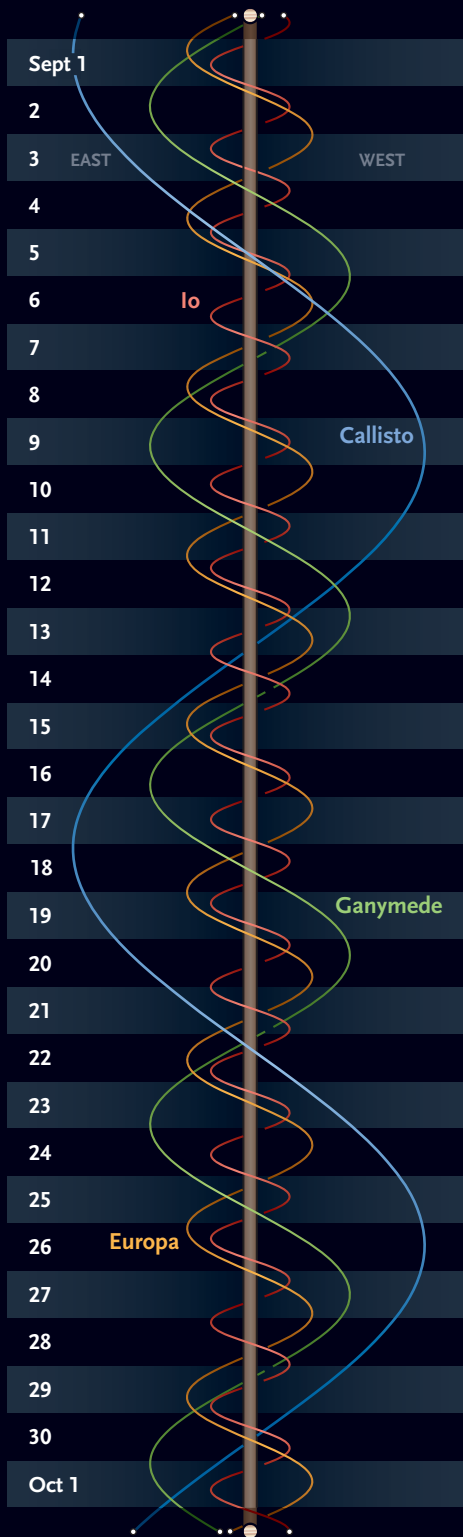
- Far beyond the asteroid belt, the trans-Neptunian object 2000 PD₃₀ may occult an 8.0-magnitude star in Aquarius for up to 6 seconds *somewhere* in the Americas, *sometime* around 6:38 September 20th Universal Time. . . plus or minus an hour or more! Objects that far away cast very uncertain occultation tracks, but timings of these events are especially desirable because such remote objects are otherwise hard to study. Check the link below for any late improvements to the prediction. If enough observers all across the continent keep watch, one or more may get lucky. This cold outer object is estimated to be 80 miles (125 km) across.

- The Moon occults Jupiter on September 8th — but only for central and southern South America in the daytime (around sunrise on the west coast).

- The Moon occults Mars on September 19th — but again only for central and southern South America, and partly in daytime (in evening twilight for some of the Atlantic coast).

Further information on these events: skypub.com/sept2012occultations.

Jupiter's Moons



The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites' positions east or west of Jupiter.

Phenomena of Jupiter's Moons, September 2012

Sept. 1	3:31	I.Oc.R	Sept. 9	0:26	I.Tr.I	4:27	I.Tr.E	Sept. 24	9:29	II.Sh.E		
	21:12	I.Sh.I		1:14	I.Sh.E	4:30	II.Sh.I		9:47	II.Tr.I		
	22:32	I.Tr.I		1:53	II.Sh.I	6:52	II.Sh.E		12:07	II.Tr.E		
	23:16	II.Sh.I		2:34	I.Tr.E	7:14	II.Tr.I		0:09	I.Ec.D		
	23:21	I.Sh.E		4:15	II.Sh.E	9:34	II.Tr.E		3:39	I.Oc.R		
Sept. 2	0:41	I.Tr.E	Sept. 10	4:39	II.Tr.I	Sept. 17	22:15	I.Ec.D	Sept. 25	21:21	I.Sh.I	
	1:38	II.Sh.E		7:00	II.Tr.E		19:28	I.Sh.I		22:38	I.Tr.I	
	2:02	II.Tr.I		20:21	I.Ec.D		20:46	I.Tr.I		23:30	I.Sh.E	
	4:23	II.Tr.E		23:54	I.Oc.R		21:36	I.Sh.E		0:46	I.Tr.E	
	18:27	I.Ec.D		17:34	I.Sh.I		22:51	II.Ec.D		1:25	II.Ec.D	
Sept. 3	22:00	I.Oc.R	Sept. 11	19:43	I.Sh.E	Sept. 18	22:55	I.Tr.E	Sept. 26	3:48	II.Ec.R	
	15:41	I.Sh.I		20:17	II.Ec.D		1:14	II.Ec.R		4:01	II.Oc.D	
	17:01	I.Tr.I		21:02	I.Tr.E		1:31	II.Oc.D		6:22	II.Oc.R	
	17:43	II.Ec.D		22:40	II.Ec.R		3:52	II.Oc.R		10:42	III.Sh.I	
	17:49	I.Sh.E		22:59	II.Oc.D		6:43	III.Sh.I		12:39	III.Sh.E	
Sept. 4	19:09	I.Tr.E	Sept. 12	2:43	III.Sh.I	Sept. 19	8:38	III.Sh.E	Sept. 27	15:59	III.Tr.I	
	20:05	II.Ec.R		4:38	III.Sh.E		12:09	III.Tr.I		17:49	III.Tr.E	
	20:25	II.Oc.D		8:14	III.Tr.I		13:59	III.Tr.E		18:37	I.Ec.D	
	22:44	III.Sh.I		10:04	III.Tr.E		16:43	I.Ec.D		22:06	I.Oc.R	
	22:47	II.Oc.R		14:49	I.Ec.D		20:15	I.Oc.R		15:49	I.Sh.I	
Sept. 5	0:38	III.Sh.E	Sept. 13	18:22	I.Oc.R	Sept. 20	13:56	I.Sh.I	Sept. 28	17:05	I.Tr.I	
	4:15	III.Tr.I		12:03	I.Sh.I		15:14	I.Tr.I		17:58	I.Sh.E	
	6:06	III.Tr.E		13:22	I.Tr.I		16:05	I.Sh.E		19:14	I.Tr.E	
	12:55	I.Ec.D		14:11	I.Sh.E		17:23	I.Tr.E		20:24	II.Sh.I	
	16:28	I.Oc.R		15:11	II.Sh.I		17:48	II.Sh.I		22:47	II.Sh.E	
Sept. 6	10:09	I.Sh.I	Sept. 14	17:57	II.Tr.I	Sept. 21	20:10	II.Sh.E	Sept. 29	23:02	II.Tr.I	
	11:29	I.Tr.I		20:17	II.Tr.E		20:30	II.Tr.I		1:22	II.Tr.E	
	12:17	I.Sh.E		Sept. 15	9:18		I.Ec.D	22:50		II.Tr.E	13:06	I.Ec.D
	12:34	II.Sh.I			12:51		I.Oc.R	11:12		I.Ec.D	16:34	I.Oc.R
	13:37	I.Tr.E			Sept. 16		6:31	I.Sh.I		14:43	I.Oc.R	10:18
14:56	II.Sh.E	7:50	I.Tr.I			Sept. 22	8:24	I.Sh.I	11:33	I.Tr.I		
15:21	II.Tr.I	8:39	I.Sh.E				9:42	I.Tr.I	12:26	I.Sh.E		
17:41	II.Tr.E	9:34	II.Ec.D	10:33			I.Sh.E	13:41	I.Tr.E			
Sept. 7	7:24	I.Ec.D	9:59	I.Tr.E			11:51	I.Tr.E	14:42	II.Ec.D		
	10:57	I.Oc.R	11:57	II.Ec.R	12:08		II.Ec.D	17:05	II.Ec.R			
	4:38	I.Sh.I	12:16	II.Oc.D	14:31	II.Ec.R	17:15	II.Oc.D				
	5:57	I.Tr.I	14:36	II.Oc.R	14:46	II.Oc.D	19:36	II.Oc.R				
	6:46	I.Sh.E	16:34	III.Ec.D	17:07	II.Oc.R	Sept. 30	0:32	III.Ec.D			
7:00	II.Ec.D	18:30	III.Ec.R	20:33	III.Ec.D	2:31		III.Ec.R				
8:06	I.Tr.E	22:06	III.Oc.D	22:31	III.Ec.R	5:46		III.Oc.D				
9:23	II.Ec.R	23:58	III.Oc.R	Sept. 23	1:58	III.Oc.D		7:34	I.Ec.D			
9:43	II.Oc.D	Sept. 17	3:46		I.Ec.D	3:50		III.Oc.R	7:37	III.Oc.R		
12:04	II.Oc.R		7:19		I.Oc.R	5:40	I.Ec.D	11:02	I.Oc.R			
12:34	III.Ec.D		Sept. 18		0:59	I.Sh.I	9:11	I.Oc.R	4:46	I.Sh.I		
14:30	III.Ec.R				2:18	I.Tr.I	2:53	I.Sh.I	6:00	I.Tr.I		
18:09	III.Oc.D			3:08	I.Sh.E	4:10	I.Tr.I	6:55	I.Sh.E			
20:01	III.Oc.R	Sept. 19		Sept. 20	5:01	I.Sh.E	8:09	I.Tr.E				
Sept. 8	1:52				I.Ec.D	6:18	I.Tr.E	9:43	II.Sh.I			
	5:25		I.Oc.R		7:06	II.Sh.I	12:06	II.Sh.E				
	23:06		I.Sh.I				12:17	II.Tr.I				
							14:37	II.Tr.E				

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 4 hours ahead of Eastern Daylight Time). Next is the satellite involved: I for Io, II Europa, III Ganymede, or IV Callisto. Next is the type of event: Oc for an occultation of the satellite behind Jupiter's limb, Ec for an eclipse by Jupiter's shadow, Tr for a transit across the planet's face, or Sh for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears (D) and ends when it reappears (R). A transit or shadow passage begins at ingress (I) and ends at egress (E). Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

So, Where Are the Wild Ducks?!

A favorite deep-sky sight of late summer and early fall is M11 in Scutum off the tail of Aquila, as noted by Gary Seronik on page 45. M11 is universally called the Wild Duck Cluster, supposedly because its stars resemble a V-shaped skein of ducks migrating south for the fall. But every observer I've asked wonders, where are the ducks? The cluster is roughly round, and if you go looking for V shapes, you see them everywhere. The most common one people see is big, points northeast (toward upper left here), and embraces the brightest part of the cluster inside it.

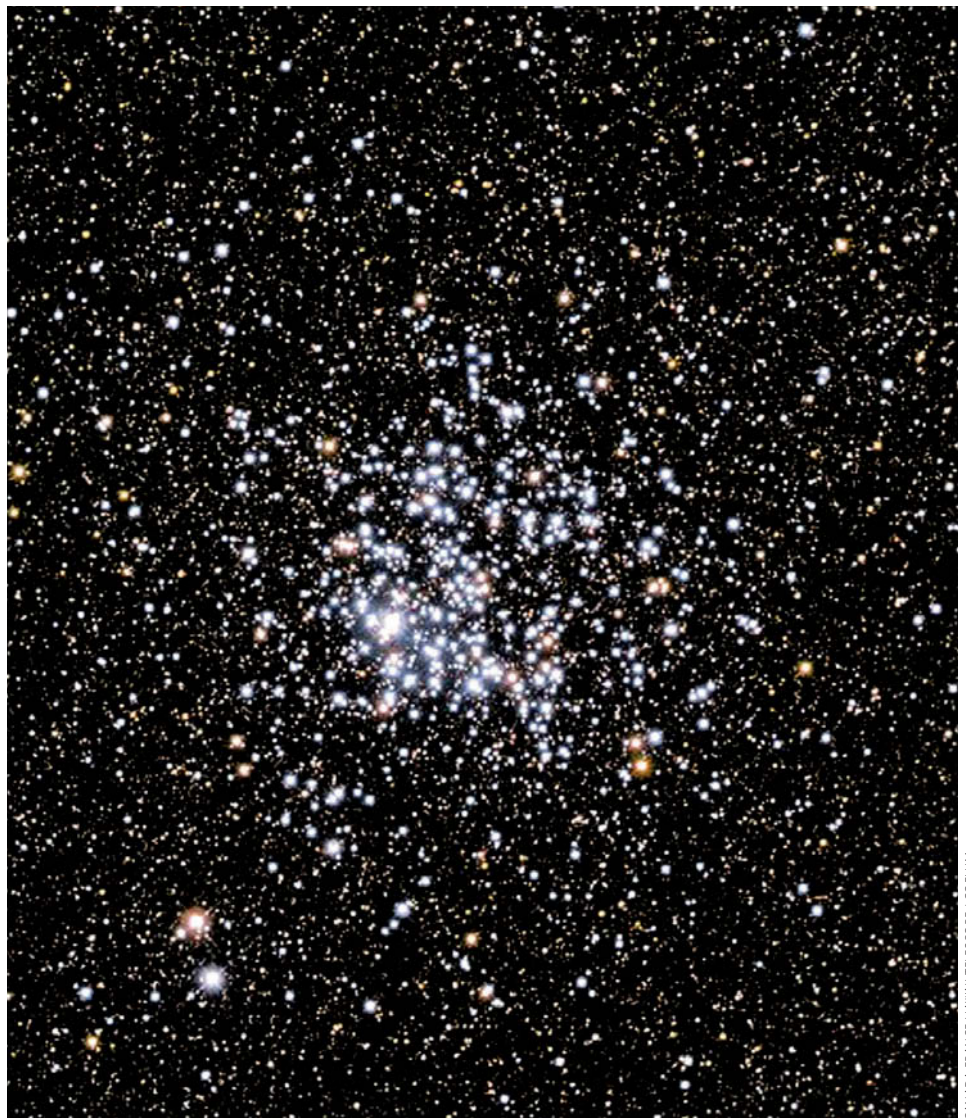
But that's not it.

The nickname comes from Admiral William H. Smyth, author of the first great telescopic observing guide: *A Cycle of Celestial Objects*, published in 1844. He called M11 "A splendid cluster of stars... which somewhat resembles a flight of wild ducks in shape." That's not much to go on. And his very rough sketch (*below*) looks like it was drawn from memory.

But the drawing provides the necessary hints. Its two bright stars can only be meant to represent the bright pair off the cluster's southeastern edge. That tells which way to look for the two arcs in the cluster. And sure enough, we see a very flattened V of stars in this location at M11's edge, and a sharper, denser V or fan deeper inside facing about the same way. Mystery solved. Go out and look.

M11 is unusually rich for an open cluster, with about 3,000 stars, but its Hertzsprung-Russell diagram reveals it to be only about 220 million years old. So it's not some kind of sparse globular cluster. It's roughly 20 light-years wide and is located about 6,200 light-years away. ♦

Compared to photos of M11, William Henry Smyth's "flight of wild ducks" sketch (*near right*) isn't very realistic at all. But the sketch does tell where to look. Sure enough, the cluster displays a broad, very flattened V of stars on the correct side and a smaller, narrower V or fan inside. These patterns are a little clearer visually than in photos. The second illustration was traced from a photo for emphasis.



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A CYCLE OF CELESTIAL OBJECTS



S&T ALAN MACROBERT

A Last Hurrah at Uranus

The 7th planet yielded one final discovery for visual observers just before its revealing Voyager close-up.

Three decades ago, when CCD imaging was in its infancy, Stephen James O'Meara determined the rotation period of Uranus using the time-honored combination of telescope and eyeball. This remarkable feat came just at the close of the long era when keen-eyed visual observers routinely recorded finer planetary details than any camera could capture.

Although Uranus is roughly four times the diameter of Earth, it is so remote that its apparent diameter never exceeds 3.7 arcseconds — 13 times smaller than Jupiter and five times smaller than Saturn at opposition. The planet's low apparent surface brightness, almost 14 times dimmer than Jupiter's, poses an even greater handicap for the observer. The lack of contrast between Uranus's pallid disk and the dark sky background also accentuates the planet's limb darkening, making it difficult to confirm whether its image is even in focus.

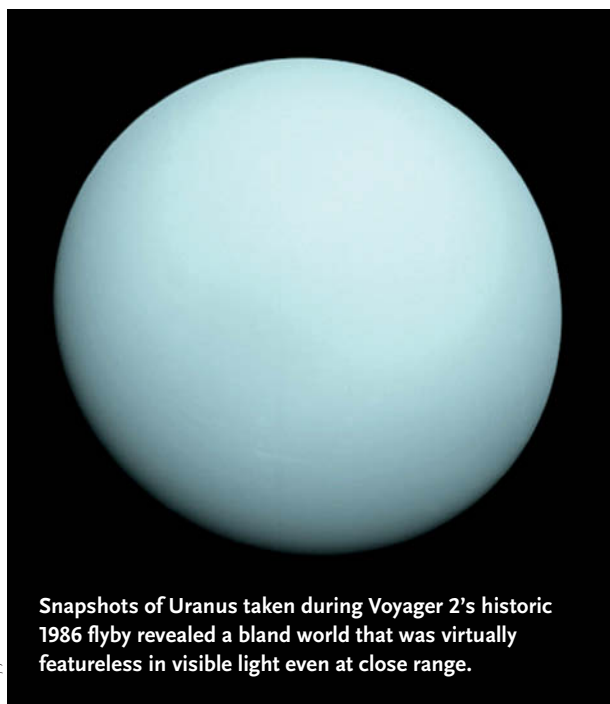
Few observers have ever managed to make out any markings on Uranus. Dusky belts and bright zones of extremely muted contrast have been reported for well

over a century, but they were usually only glimpsed as uncertain, fleeting impressions. Belief in the presence of markings on Uranus waned in 1970 after the Stratoscope II balloon lofted a 36-inch telescope to an altitude of 80,000 feet and obtained images of Uranus free from the effects of atmospheric turbulence. The planet proved to be utterly featureless in visible light, although the Stratoscope telescope detected a dappling of prominent dark spots on the far smaller disk of Jupiter's satellite Io.

Unable to follow the motion of any well-defined markings, astronomers attempting to determine the velocity of Uranus's axial rotation employed spectrographs to measure the magnitude of the equal but opposite Doppler shifts in sunlight reflected from the planet's approaching and receding limbs. The accuracy of this technique is extremely sensitive to guiding errors and atmospheric turbulence, and with Uranus it's further complicated by the fact that the planet's rotational axis is inclined by a whopping 98° to the plane of its orbit. Uranus rolls along in its orbit on its side almost pole-first while making its 84-year-long circuit of the Sun. The planet's poles are alternately pointed almost directly at the Earth at 42-year intervals. In 1944 the planet's north pole appeared near the center of its disk, while in 1986 its south pole was similarly presented. At the intervening equinoxes the planet's equator faces Earth, as was the case in 1966 and 2007.

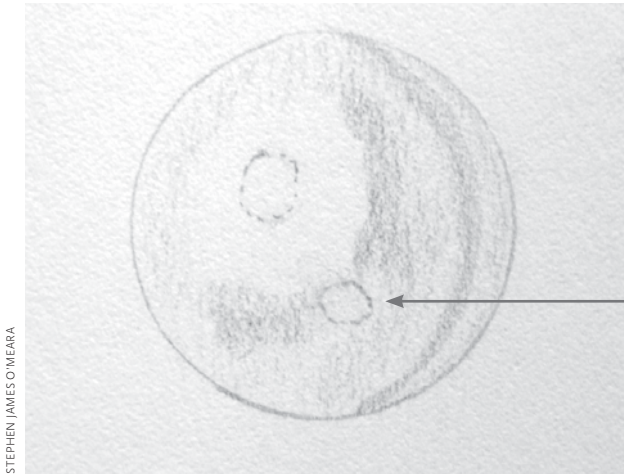
Given these daunting challenges, it's hardly surprising that rotation periods determined spectrographically were wildly discordant. Early in the 20th century a period of 10.8 hours was widely accepted, but 1977 brought a flurry of new values. Astronomers from Caltech and the University of Wisconsin suggested a rotation period of 12.3 hours, almost twice the spin rate derived by a team of University of Texas investigators, who proposed a period of just under 24 hours. Robert Brown and Richard Goody of Harvard University's Center for Earth and Planetary Physics derived a period of 15.6 hours from spectrograms made with the Kitt Peak National Observatory's 4-meter reflector, which they soon revised to 16.3 hours.

1977 was also the year that NASA launched the Voyager 1 and Voyager 2 spacecraft on a "Grand Tour" mission to the outer planets that featured a Voyager 2 close encounter with Uranus in January 1986. When the outbound



Snapshots of Uranus taken during Voyager 2's historic 1986 flyby revealed a bland world that was virtually featureless in visible light even at close range.

NASA / JPL



Stephen O'Meara exaggerated contrasts in this drawing of Uranus on September 15, 1981. The motion of this bright cloud over a period of a week revealed a 16.4-hour rotation period.

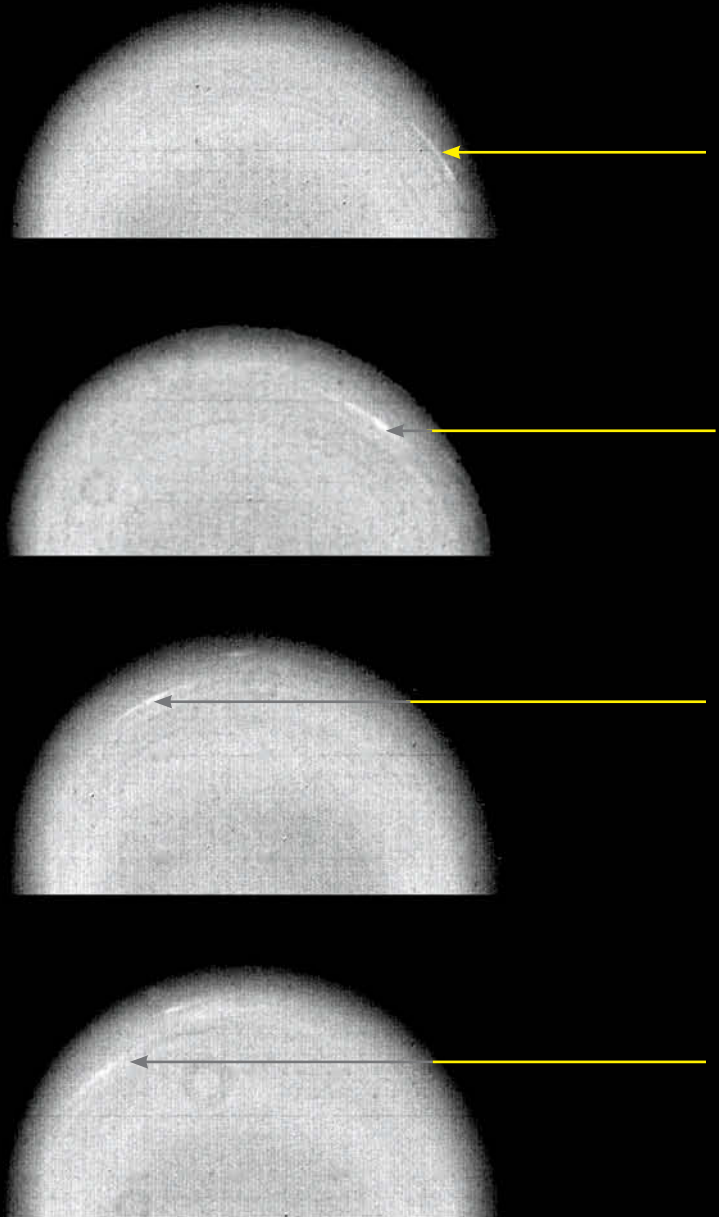
Voyagers flew past Saturn they returned images that verified the existence of the ghostly “spokes” in Saturn’s B ring that O’Meara had reported three years earlier (*S&T*: July 2011, page 50). Bradford Smith, the leader of the Voyager imaging team, marveled at O’Meara’s prowess as an observer and challenged him to try to determine the rotation period of Uranus.

For months O’Meara saw only the limb darkening of a disappointingly bland globe through the Harvard College Observatory’s venerable 9-inch Clark refractor, until two brilliant spots suddenly appeared on the night of July 22, 1981. One of these features seemed to be stationary, marking the position of the planet’s south pole, while the other was located closer to the limb. Taken aback, O’Meara rushed out of the dome, sprinted across a catwalk, and ran down a spiral staircase to the office of Michael Rudenko, a frequent observing companion.

“Another member of the staff, Peter Collins, was also there,” O’Meara recalls. “I asked them to come up to the dome and take a look at Uranus. I didn’t tell them anything about what I saw and merely asked what they could see. They both told me that they could see a pair of “stars” on the planet. . . . In fact, Peter Collins said that Uranus looked like the Ring Nebula with two central stars rather than one. That’s how bright and obvious these clouds were!”

The spots persisted for several weeks. Their relative motion between July 23rd and August 28th suggested a rotation period of 16.0 hours, while a second series of observations between September 8th and 15th yielded a value of 16.4 hours. A third remarkably bright but very-short-lived cloud observed on August 27th and 28th indicated a 16.0-hour period.

Voyager 2 Captures Clouds



This sequence of Voyager 2 orange-light images records the motion of a bright, streaky cloud over an interval of 4.6 hours on January 14, 1986. The donut-shaped blemishes are shadows cast by motes of dust in the camera’s optics.

When Richard Goody learned that O'Meara's visual observations confirmed the rotation period that he had determined spectrographically several years earlier, he implored O'Meara to publish his results. But the cautious Brian Marsden, Director of the Central Bureau for Astronomical Telegrams, balked at issuing an announcement. To convince Marsden that O'Meara's observations were credible and worthy of publication, Rudenko and another member of the observatory staff, Daniel Green, devised an experiment. Seven artists' depictions of Uranus that closely approximated the planet's tiny apparent size were affixed to the railing of a tall building located one kilometer from the refractor's dome. O'Meara, Rudenko, and Green took turns at the eyepiece and made sketches. O'Meara's were consistently the most detailed, accurately recording features on the order of only 0.5 arcsecond wide.

His skepticism mollified by these results, Marsden announced O'Meara's visual discovery in International Astronomical Union Circular 3912, issued in early 1984. Two years later the motions of several bright clouds were recorded in contrast-enhanced Voyager 2 images. They revealed that features in the temperate latitudes (where two of O'Meara's three spots appeared) circle the planet within minutes of the periods he derived.

The Voyager 2 images were as perplexing as they were gratifying. The level of contrast for the handful of features that could be distinguished amidst the hydrocarbon hazes of Uranus's cold, deep atmosphere in visible wavelengths was so low that it seemed utterly implausible that any visual observer could have seen so much as a hint of them. In the decades following his 1981 observations, O'Meara has never seen another well-defined feature on Uranus, even though he has studied the planet through telescopes as large as the 60-inch Mount Wilson reflector.

In retrospect, Uranus seems to have been unusually quiescent during the 1986 Voyager 2 flyby. In 1994 the Hubble Space Telescope recorded a pair of bright convective clouds that were strikingly similar to the features observed by O'Meara in 1981. Since 2004 several large ground-based telescopes equipped with adaptive optics



S&T: SEAN WALKER

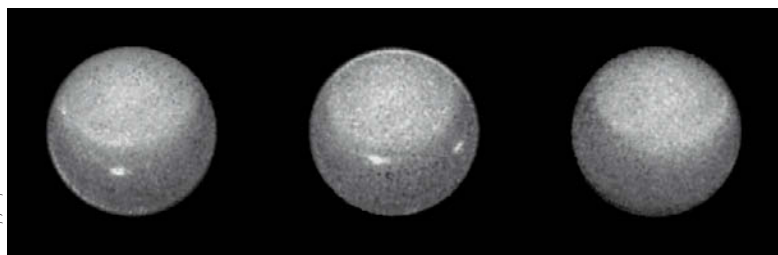
Former *Sky & Telescope* editor Stephen O'Meara used this 9-inch Alvan Clark refractor, housed in an observatory atop the Harvard-Smithsonian Center for Astrophysics, to study Uranus in 1981.

have recorded belts, zones, and periodic outbreaks of bright spots in near-infrared wavelengths, where these features display much higher contrast than in visible light. Uranus is proving to be far more dynamic than once thought. Long-term studies may reveal that the wildly exaggerated seasons that result from the planet's 98° axial tilt greatly influence its level of atmospheric activity.

Although Uranus is not a memorable spectacle, bear in mind the experience of the first observer to report seeing "fairly definite features," British amateur T. H. Buffham. Using a 9-inch Newtonian reflector at magnifications of 212× and 320× on two nights in January 1870, Buffham noticed "two round bright spots" on Uranus. Over the course of an hour on the first night he was able to discern that they were moving. Based on their nearly identical positions two nights later, he guessed that Uranus had rotated on its axis four times during the intervening 48 hours and proposed a period of about 12 hours in a report published in *The Astronomical Register* three years later.

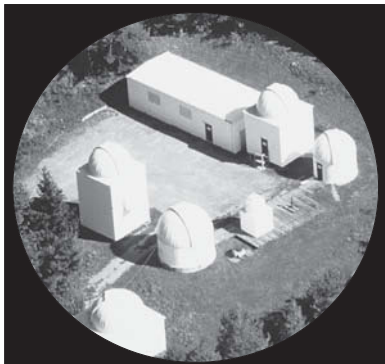
Had Buffham made the equally plausible guess of three rotations, corresponding to a period of about 16 hours, he would have beat O'Meara to the punch by more than a century. Buffham and O'Meara employed telescopes of the same modest aperture at similar magnifications and saw transient bright spots moving at the same rate. Is this merely a remarkable coincidence, or proof that on rare occasions Uranus can be a rewarding target for telescopes of modest aperture?

Uranus comes to opposition this month (see page 50). See if you can spot any features in the planet's usually bland atmosphere. ♦



NASA / JPL / STSCI

Acquired by NASA's Hubble Space Telescope on August 14, 1994, these near-infrared images of Uranus capture a pair of bright clouds and the high-altitude haze that forms a bright "cap" above the planet's south pole. The resemblance to O'Meara's 1981 depictions of the planet is striking.



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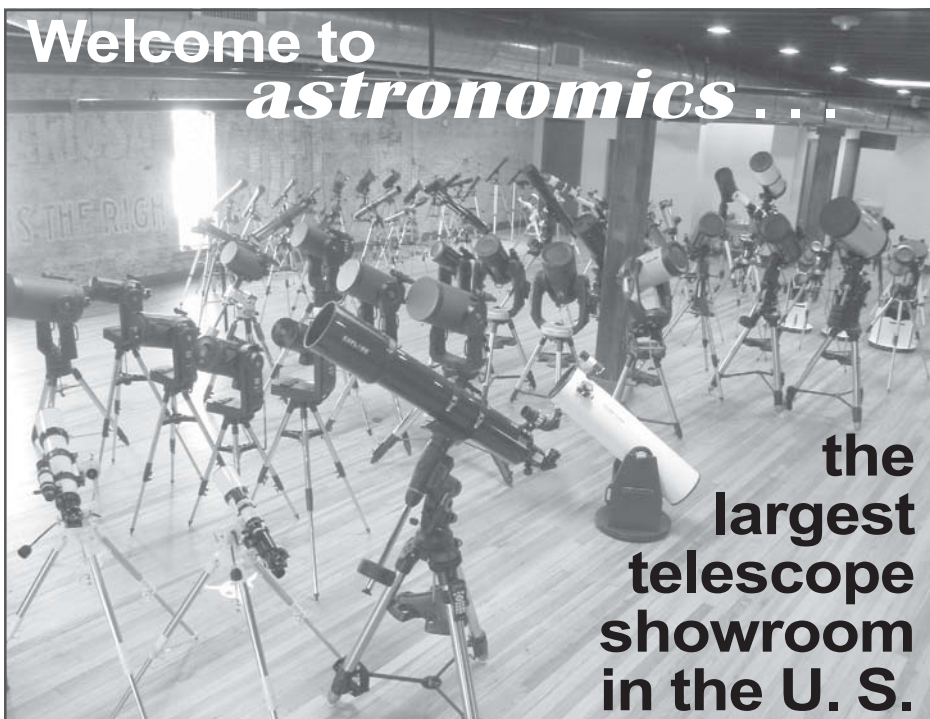
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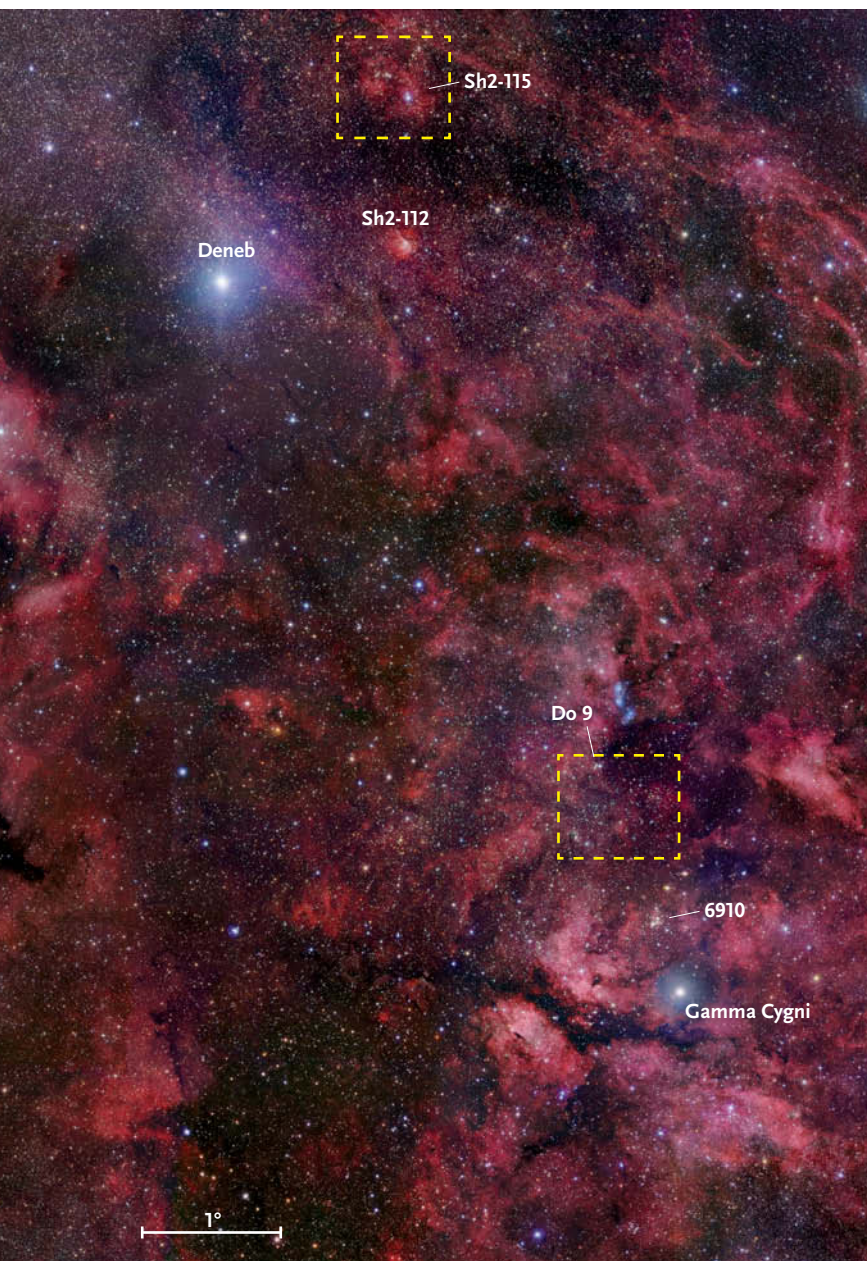
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Guide Me, Cygnus

The area around Deneb and Gamma Cygni is amazingly rich.



The area around and between Deneb and Gamma Cygni includes hundreds of named nebulae and clusters; only the ones discussed in this article are labeled. Close-ups of the areas around Dolidze 9 and Sharpless 2-115 are shown on pages 59 and 60, respectively. Some labels have been omitted in these areas for clarity. See page 63 for a detailed discussion of the Gamma Cygni Nebula, which dominates the southwestern corner of this photo.

*Guide me, Cygnus, I may be alone
Except for you. In the Summer hang above me,
And in the Autumn face me from the west,
And then in Winter I shall strive alone, —
Alone until the Spring and your return.*

— Laurence Carter, *Cygnus*, 1921

Cygnus, the Swan, accompanies us through most of the year. During cool September evenings, with the coloring leaves whispering in the dark, he flies high on silent pinions, gliding through the zenith on his westerling flight.

In this month's sky tour, we'll visit some of the deep-sky wonders sheltered in the crook between the Swan's tail (marked by brilliant Deneb) and his northern wing. Our first will be the attractively peculiar open cluster **NGC 6910**, perched just 33' north-northeast of Gamma (γ) Cygni, also known as Sadr. My 105-mm refractor at 87× shows a 5' pattern that reminds me of a toy horse on wheels. Two bright, golden stars mark the wheels, while eight fainter stars of nearly equal magnitude shape the northwest-bound horse. A half-dozen very faint stars complete the cluster. I was not at all surprised to learn that NGC 6910 is sometimes called the Rocking Horse Cluster, which requires only a slightly different twist of the imagination to see.

My 10-inch reflector at 68× reveals 24 bright to faint stars gathered in 9', many in striking star-chains. Large areas of nebulosity line the eastern and western sides of the field of view. Indeed, much of this part of the sky is raggedly fogged by patches of the vast Gamma Cygni Nebula (IC 1318), a complex of bright and dark nebulae that mantles nearly 4° of sky. The Gamma Cygni Nebula is discussed in detail in this month's *Going Deep* column on page 63.

NGC 6910 is a very young cluster, with an age of about 13 million years. It holds many hot, blue-white stars, including the bright star at the horse's rear wheel. Approximately 3,700 light-years away from us, this star is dimmed by three magnitudes and yellowed by copious amounts of intervening dust grains in the plane of the Milky Way.

A nice triangle of open clusters is centered 58' north-northeast of NGC 6910. Dolidze 9, Collinder 421, and Dolidze 11 share a field of view through any eyepiece that gives you a true field of 47' or more.

ROBERT GENDLER



The northernmost cluster is **Dolidze 9**. Through my 130-mm refractor at 23×, I see three stars and a hint of fainter ones. The easternmost star is brightest at 7th magnitude, and the second-brightest star appears yellow. At 102×, eight stars form a Y shape with the base pointed west. Connecting the end of each branch of the Y with imaginary lines boxes the stars into an equilateral triangle with 3.4' sides. I see only four additional stars within the nominal 7' diameter of the cluster. The 10-inch scope at 68× exposes 22 stars, while the cluster and the sky to its north and east look nebulous.

Collinder 421 is centered 28' west-southwest of Dolidze 9. It's a nice little misty spot sprinkled with several faint stars through the 130-mm scope at 23×. At 102× the cluster shows 22 moderately faint to faint stars loosely sprinkled over 8' of sky. Cr 421 stands out fairly well from the background in my 10-inch reflector at 68×, with an isosceles triangle of three 10th-magnitude stars embedded in the western side of a collection of a dozen fainter stars. At 115× about 30 stars bunch into an 8' group with indefinite borders. The triangle's southern stars look orange, and the northern one shines golden. A misty glow entangles the cluster and spreads to its west.

Look 31' south-southeast of Dolidze 9 for a 9' arc of five stars, magnitude 7½ to 10. All but the brightest one curve across the face of **Dolidze 11**. A few very faint stars cluster around the four-star arc through my 130-mm scope at 23×. At 102× the brightest star appears yellow, and a baker's dozen of faint stars plumps the group to about 7'. A close, faint star pair sits 1.8' west of the cluster's yellow gem. Dolidze 11 displays some nebulosity around the arc



Most of NGC 6910's stars are very hot and blue, but they appear yellow due to the dust between them and us.

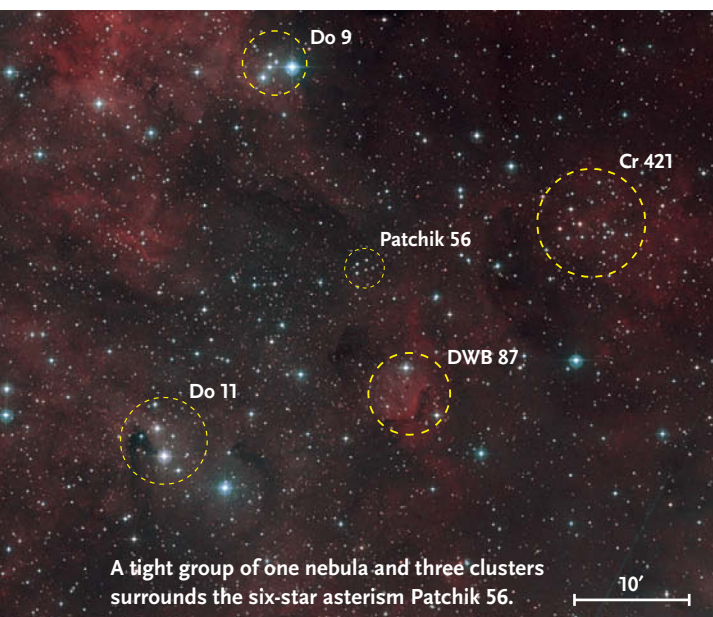
STEFAN BINNEWIES / JOSEF POPSEL

stars, darker sky to their east, and then brighter nebulosity beyond that.

Estimates of the distances to Do 9, Do 11, and Cr 421 are 2,800, 3,700, and 3,100 light-years, respectively, while their ages are assessed at 20 million, 400 million, and 1 billion years.

A 9th-magnitude star lies about halfway between and a little south of an imaginary line connecting Dolidze 11 and Collinder 421. In my 10-inch reflector at 68×, this star sits at the northern rim of the relatively bright nebula **DWB 87**. This nebula covers about 5' with a 10th-magnitude star at its west-southwestern edge and a 12th-magnitude star in its east-southeastern edge.

The designation DWB comes from the 1969 catalog of

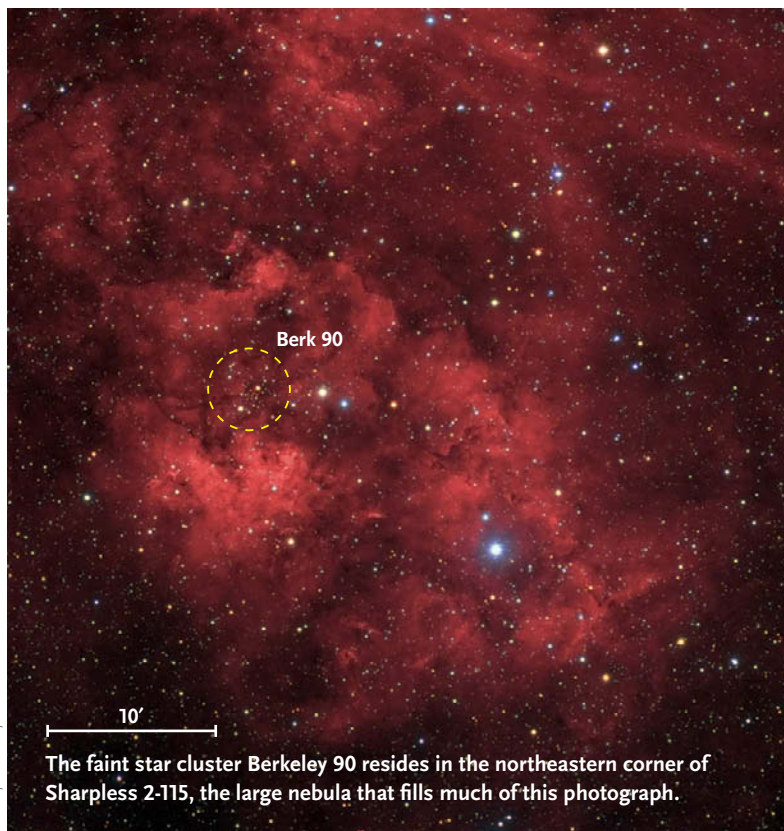


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Selected Gems in Northern Cygnus

Object	Type	Mag(v)	Size	RA	Dec.
NGC 6910	Open cluster	7.4	10'	20 ^h 23.2 ^m	+40° 47'
Dolidze 9	Open cluster	—	7'	20 ^h 25.5 ^m	+41° 54'
Collinder 421	Open cluster	10.1	8'	20 ^h 23.3 ^m	+41° 42'
Dolidze 11	Open cluster	—	7'	20 ^h 26.4 ^m	+41° 25'
DWB 87	Emission nebula	—	7.8' × 4.3'	20 ^h 24.6 ^m	+41° 27'
Patchik 56	Asterism	—	3.3' × 2.2'	20 ^h 24.9 ^m	+41° 37'
Sh 2-112	Emission nebula	—	15'	20 ^h 34.1 ^m	+45° 39'
Sh 2-115	Emission nebula	—	30' × 20'	20 ^h 34.5 ^m	+46° 49'
Berkeley 90	Open cluster	—	5'	20 ^h 35.2 ^m	+46° 51'

Angular sizes are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.



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The faint star cluster Berkeley 90 resides in the northeastern corner of Sharpless 2-115, the large nebula that fills much of this photograph.

emission nebulae by Helene Dickel, Heinrich Wendker, and John Bieritz. The catalog lists 193 nebulae in the region surrounding Gamma Cygni.

While observing this area with my 10-inch scope at 68×, I noticed a distinctive little asterism halfway between and a little north of an imaginary line connecting Dolidze 11 and Collinder 421. This star bunch was first noted by California amateur Dana Patchick and is known as **Patchick 56**. Six faint stars form a 2.4'-long group like a little leaping dolphin. At 213× Patchick 56 garners four more stars that swell it to 3.2' north-south and 2' east-west.

Although many other deep-sky delights inhabit this

region, let's jump northward and twice as deep into space to visit the emission nebulae Sharpless 2-112 and Sharpless 2-115.

Sharpless 2-112 dwells 1.3° west-northwest of Deneb. With a narrowband nebula filter and my 130-mm scope at 23×, this emission nebula is a faint teardrop dripping southward from a 9th-magnitude star. An O III filter gives a dark view but shows the nebula spreading a bit farther eastward.

Sh 2-112 is easily visible through the 10-inch reflector at 68×, and it shares the field with a large, dog-like asterism of stars southeast. The nebula appears larger with this scope, and the 9th-magnitude star adorns its northwestern edge. Just off the nebula's opposite side, an orange 10th-magnitude star decorates the view. A narrowband filter reveals faint nebulosity northwest of the 9th-magnitude star and divided from it by a dark rift. At 115× the patchy nebula and dark rift show rather well without a filter and cover roughly 11'. The filterless view also favors the visibility of the faint stars enmeshed in the haze.

Climbing 1.2° due north takes us to **Sharpless 2-115**. My 130-mm refractor at 37× exhibits an intricate tapestry of light and dark. This lovely nebula engulfs two bright, very wide star pairs, with the brighter star of the northeastern pair boasting a golden hue. Fairly bright nebulosity lies southeast of this star and is disconnected from a fainter swath to the north. The nebula is also bright around the southwestern pair, where it is wide and elongated north-south. The entire nebula spans about 27' × 15'. The open cluster **Berkeley 90** rests just east of the golden star. At 117× it looks like a 3' patch of fog enveloping two moderately faint and four very faint stars. The cluster is not particularly obvious even in my 10-inch scope at 166×. I see a 4¼' × 3¼', north-south oval of 16 stars. The three brightest are likely foreground stars, but the faint ones are more densely crowded than similar field stars around them.

On your next clear night, let Cygnus guide you and reveal the some of the many riches he carries with him on his nightly flight across the sky. ♦

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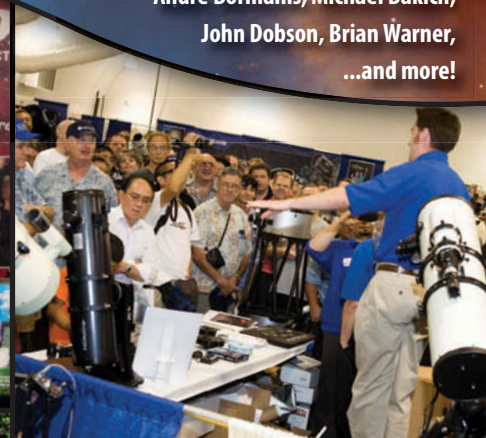
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The Gamma Cygni Nebula

This huge complex is both challenging and rewarding.

SADR (GAMMA CYGNI) may have won a celestial lottery for one of the prime locations in the sky. It marks the breast of the celestial Swan and the center of the Northern Cross. It's also near the northernmost points of the Cygnus Star Cloud and the Milky Way's Great Rift. In addition, Sadr is surrounded by a rich tapestry of glittering stars, dark absorption lanes, and the H II complex IC 1318, which sprawls across 4° of exclusive Milky Way property. Edward Emerson Barnard, who discovered IC 1318 photographically at Lick Observatory in 1892, described the Gamma Cygni region as "extraordinary from the vast amounts of nebulosity . . . in tufts and masses and sheets of filmy light."

Although Sadr appears to be directly involved with this nebulosity, it's actually a foreground star. Sadr is an F8 supergiant approximately 1,800 light-years away — a huge distance for a star that appears so bright. But IC 1318 lies far behind it at a distance of 4,500 to 5,000 light-years.

IC 1318 provides a stunning vista for imagers, with billowing red patches and elongated strips of nebulosity broken up by broad swaths of dust. Visually, though, this is a fairly difficult object due to its large size and low surface brightness. To guarantee success you'll need dark skies, low power, and appropriate filters. IC 1318 has no oxygen emissions, so it does not respond to an O III filter. A hydrogen-beta (H β) filter shows the nebulosity best, while a narrowband (UHC) filter that passes both H β and O III emissions yields brighter stars but less contrast in the nebula.

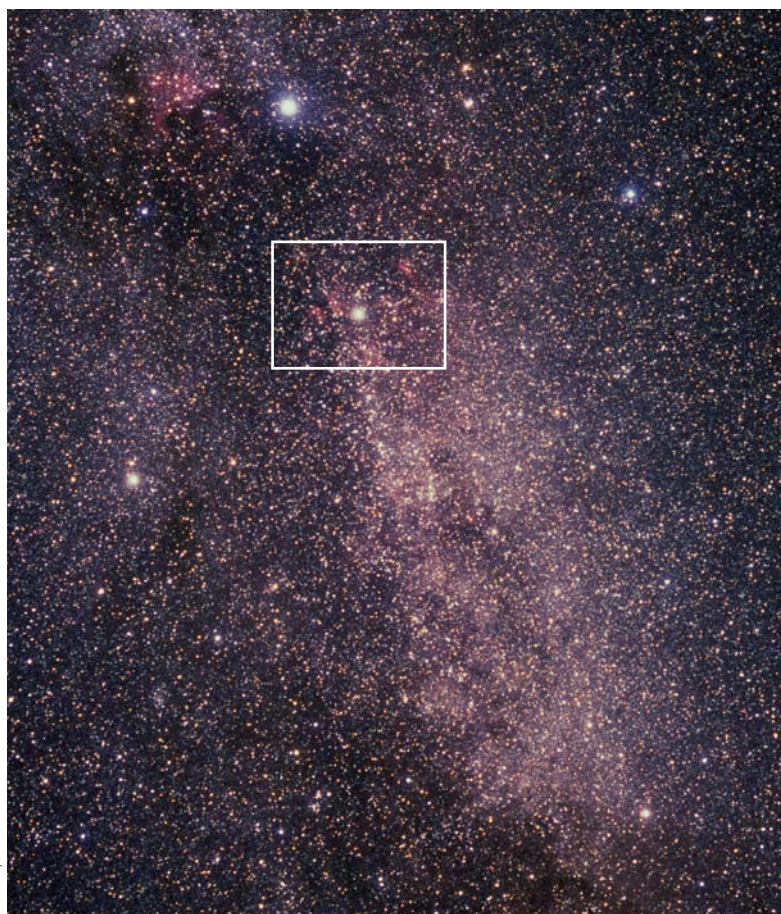
My first look was in 1984 on an exceptional night in California's High Sierra. Using an 80-mm finder at 16× with an H β filter, I was shocked by the view — five large patches of irregular nebulosity filled the 4° field! A prominent fragment was easily visible northwest of Sadr along with two parallel ribbons to the east of this star.

Since then I've viewed this region numerous times using a variety of instruments from 15×50 binoculars to my 18-inch Dobsonian. Smaller instruments with wider fields frame more of the diffuse nebulosity, and larger scopes reveal more dusty and wispy details.

The individual components of IC 1318 have been assigned a variety of catalog designations by Beverly Lynds (LDN), Stewart Sharpless (Sh), and Sven Cederblad (Ced). Edwin Hubble and other researchers have also assigned various letter designations to IC 1318. For simplicity, I've followed the lettering scheme used by the *Uranometria 2000.0 Deep Sky Atlas* (2nd edition, Chart A2).

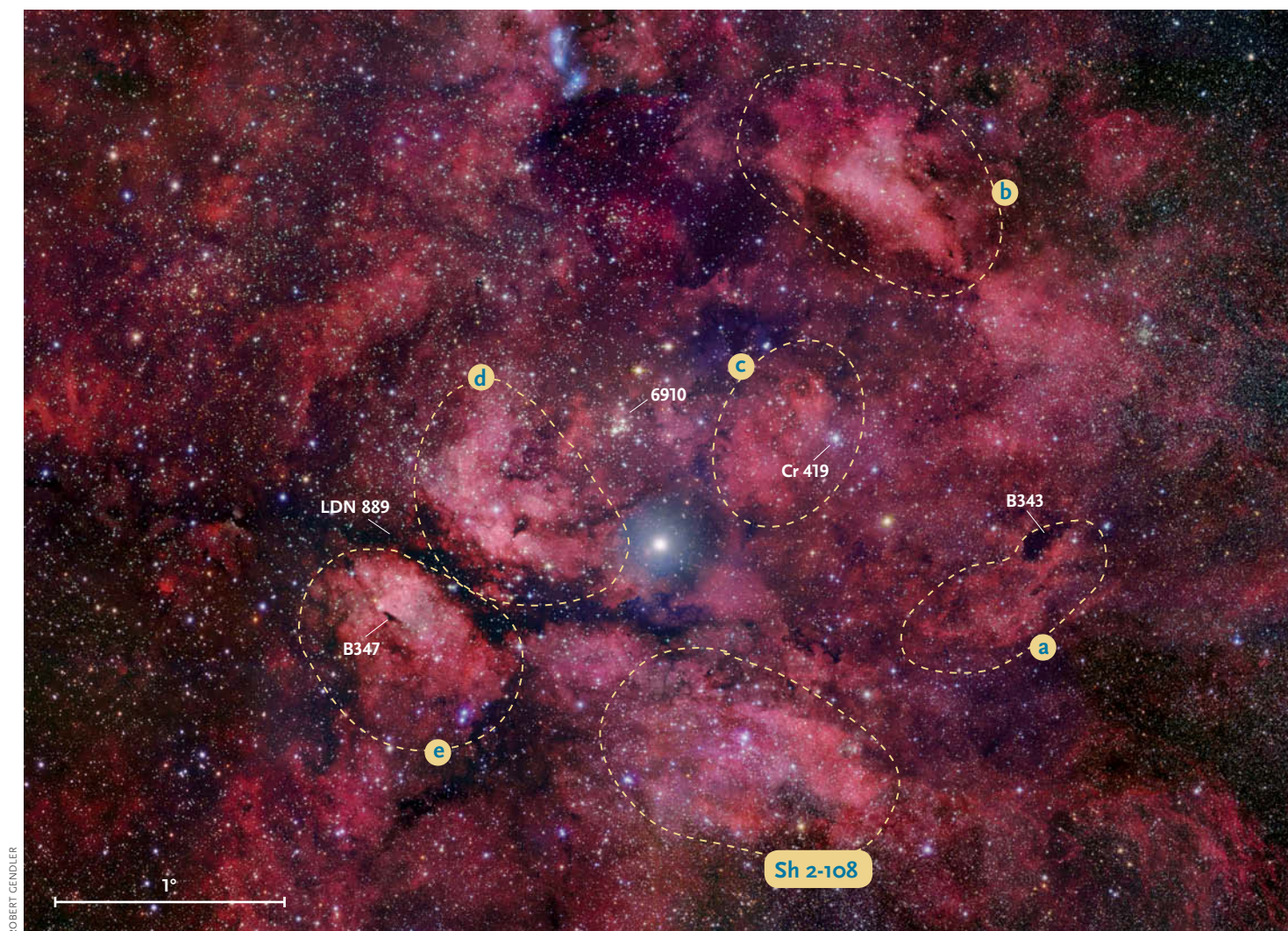
Let's start with **IC 1318(b)**, a narrow wedge situated 2° northwest of Sadr. In my 18-inch it spans 40' × 8', with an 8th-magnitude star near its center. The brightest portion spreads out northeast from this star, while the fainter southwest end thins and curves slightly toward the south. A hazy extension juts out from the north side.

IC 1318(d) and **IC 1318(e)**, centered 1° east of Sadr, form a pair of celestial wings nicknamed the "Butterfly Nebula." This field is an astonishing sight in my 18-inch, with two glowing swaths of nebulosity fractured by the broad dark lane **LDN 889**.



AGRA FUJII

The Gamma Cygni Nebula lies at the heart of the Northern Cross. The outlined area is shown in more detail on the page 64.



ROBERT GENDLER

The objects discussed in this article are labeled, but the photograph includes many more named objects (see, for instance, page 58). Sections of IC 1318, such as IC 1318(a), are labeled only with the letter. Gamma Cygni is the bright star south-southwest of NGC 6910.

IC 1318(d) passes through the two 7th-magnitude stars, coursing southwest and northeast. North of these stars the nebulosity widens and appears interspersed with darker patches. In my 18-inch, scalloped edges and ragged shreds embellish the border with LDN 889.

IC 1318(e), on the south side of the black rift, passes through several wide double stars as it sweeps southwest to northeast, extending at least $35' \times 10'$. Look for **Barnard 347**, a dark streak near the center.

Sh 2-108, located 1° south-southwest of Sadr, is visible in my 80-mm finder as a $60' \times 40'$ oval glow. The edges can be clearly traced in my 18-inch, forming a kidney-shape outline with a darker bay on the south side harboring a 6.4-magnitude star.

The remaining sections are significantly fainter and require good conditions to identify. **IC 1318(a)** is an irregular gossamer glow, roughly $45'$ in size, residing 1.6° west of Sadr. A slightly brighter patch on the northwest side marks the border with the dark nebula **Barnard 343**.

Finally, let's head $45'$ northwest of Sadr to the scattered cluster **Collinder 419**. This group is highlighted by $\Sigma 2666$, a tight $2.7''$ pair of 6th- and 8th-magnitude stars. Three-dozen stars radiate outward in strings from the bright double. Cr 419 is involved with **IC 1318(c)**, a low-contrast patch. The surrounding field seems patchy unfiltered, with slightly darker and brighter regions. Adding a UHC filter confirms that Cr 419 is encased in a gauzy mist that opens east in a fan shape.

At this point, take a break from straining your eyes and hop over to **NGC 6910**, a bright knot of several dozen stars just $40'$ north-northeast of Sadr. This issue's *Deep-Sky Wonders* column (page 58) discusses this cluster and several more nearby. But the riches of northern Cygnus are impossible to exhaust; there are always many more challenging clusters and nebulae waiting to be explored. ♦

Steve Gottlieb welcomes your comments and questions at steve_gottlieb@comcast.net.

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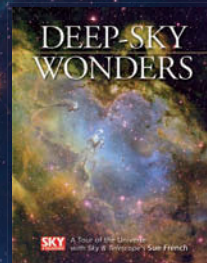
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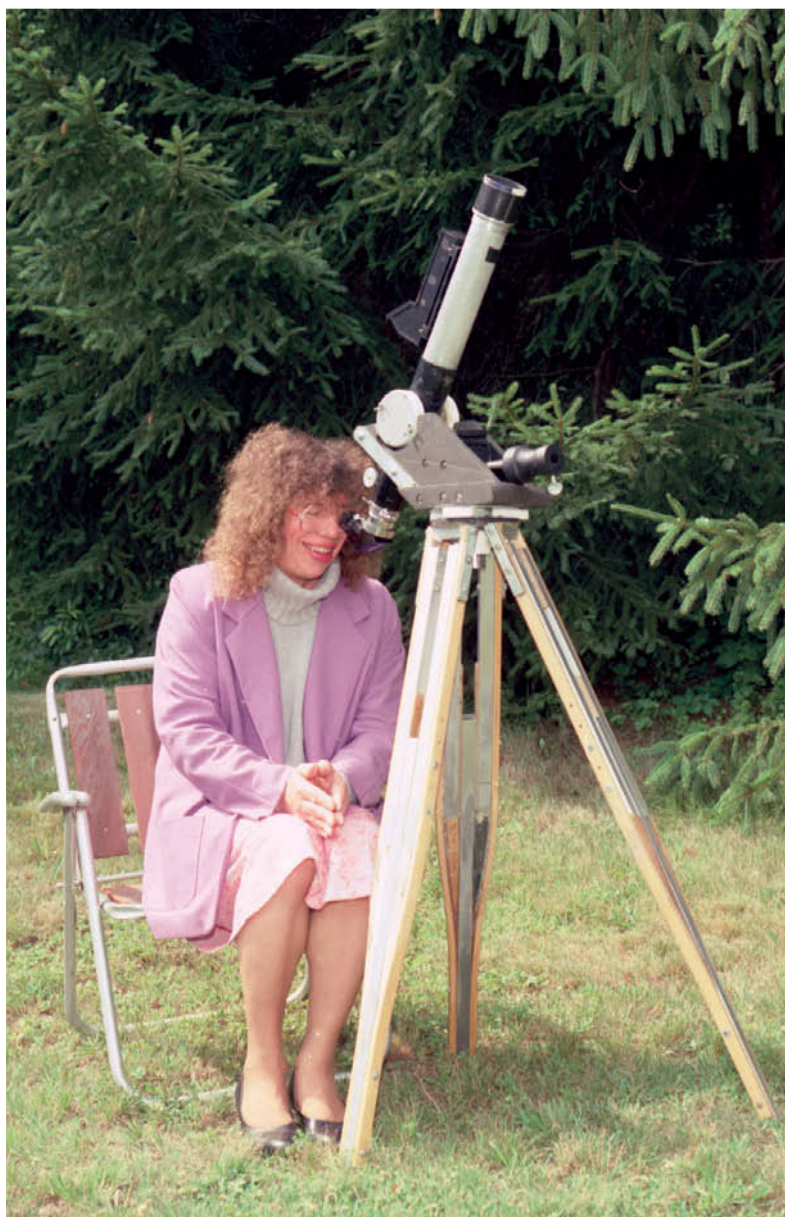
Can I interest you in a research project?

I'm begging for volunteers from both hemispheres to observe a few double stars. There's no measuring involved, any size telescope is okay, and you don't need to be an experienced observer. If all goes well, we can answer a question that has dogged double-star observers for 150 years. I should probably begin with a general introduction to double-star observing, for those new to this activity. But experienced observers can skip the next paragraph and go right to the heart of the project.

Double stars are the jewels of the heavens, each with its own combination of colors, magnitude difference, and space between the two stars. They're perfect targets for hazy nights and small telescopes because they're so bright and crisp compared to the soft clouds of distant clusters and galaxies. And their fantastic colors, such as "slight yellow and pale garnet," "orange and smalt blue," and "light rose tint and dusty red" (quotes from Admiral W. H. Smyth), can be breathtaking. Some are line-of-sight coincidences called *optical doubles*: their stars are actually light-years apart and not physically connected. The others are physical pairs called *binary stars*: their members are usually less than 1% of a light-year apart, and are bound together by mutual gravity. The fainter member of a pair is called the *companion*. The apparent visual space between the two stars is called their *separation*. It's usually measured in *arcseconds* ("). A 30" pair is wide, 15" is medium, and 3" or less is close. Most wide pairs are optical and most close pairs are binary.

How much aperture do you need to split a close pair — that is, see it's really two stars rather than one? The Reverend William R. Dawes answered this question for pairs of equally bright stars in 1859. Ever since, observers have tried to find a formula that works just as well for unequal pairs.

Let me explain all this a bit more. The Dawes formula says that the minimum separation splittable by a telescope is $4.56''$ divided by the aperture in inches, or $116''$ divided by the aperture in mm. This indicates that my



The author poses with her 60-mm f/15 refractor. The tripod of her homemade alt-azimuth mount is built from crutches.

SKY & CHUCK BAKER

Uneven Double Stars

Your observations can contribute to this important project.

Gamma Virginis (Porrima)



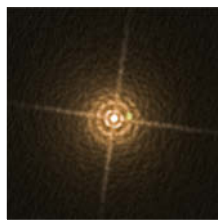
Resolution of even pairs such as Gamma Virginis (shown here) is limited by the size of the Airy disk, the center of the diffraction pattern. Double-star observer and graphic artist Jeremy Perez sketched Gamma (left to right) when it was slightly below the 0.76" Dawes limit for his 6-inch reflector, slightly above the limit, and comfortably above the limit.

60-mm refractor can split equal pairs 1.9" or wider, since $116/60 = 1.9$. Thus, 1.9" is known as the Dawes limit for my 60-mm. It doesn't mean I will always split pairs this tight, but it means it should be possible with good eyesight and excellent optics under a good sky.

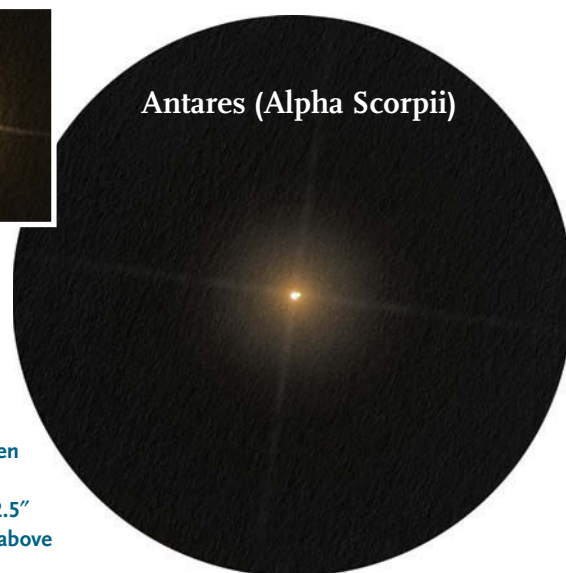
The Dawes formula is tried and true, but it only works when the pair is 6th magnitude or brighter, and made of two stars similar in brightness. When the members are different by a magnitude or more, a scope won't perform at the Dawes limit. For example, compare Mu (μ) Draconis with Gamma (γ) Ceti, as shown on the following page. Their separations are almost identical. But Mu Draconis is a pair of twins whereas Gamma Ceti is uneven by nearly three magnitudes. My 60-mm scope clearly shows that Mu is a double star, but no sign at all that Gamma is one. My 125-mm f/10 refractor splits Gamma about as easily as my 60-mm splits Mu, but I know this only from experience. There are no formulas as reliable as Dawes's for predicting it. Double-star enthusiasts have been trying to come up with such a formula ever since Dawes published his result more than a century ago.

When I wrote a regular *Sky & Telescope* column on double stars, I received more mail about this subject than any other. I found six published formulas for unequal doubles from my own research. The only thing they

agree on is that pairs that are unequal by a magnitude or more need more separation than the Dawes limit. But none of them predict aperture as well as Dawes does for equal pairs, with the possible exception of Christopher Lord's nomogram (*S&T*: January 2002, p. 118). Lord's numbers may be right, but I know of no observational study that has tested them.



Perez found Antares difficult to split in his 6-inch scope due to the 4.4-magnitude difference between its components, even though its 2.5" separation is far above the Dawes limit.



Antares (Alpha Scorpii)

This leads us, finally, to the heart and purpose of this article. Why not answer the question once and for all with actual observations? The table on the next page shows representative pairs in increments of separation and magnitude difference. The data is taken from the online *Washington Double Star Catalog*, as of March 2011. I stuck with bright pairs that won't show significant changes within our lifetimes. Unfortunately, there isn't a pair for every position on the chart, and many are too far north or south for observers in the opposite hemisphere. Also, not all the pairs fit the chart perfectly. For example, Struve 389 (Σ 389) is actually 2.6" rather than the 2.5" that its line calls for. But I can only chart what actually exists, and the inaccuracies are too small to affect the study seriously. I might find pairs fainter than 7th magnitude to fill in the gaps and make the numbers perfect, but their extremely faint companion stars would place them beyond the reach of typical amateur telescopes. For example, even my 325-mm (13-inch) Coulter Dobsonian won't show me unequal 11th-magnitude companions, unless they're wider than 4".

I can't compile all the observations myself, since I don't own a telescope of every size and can't see any

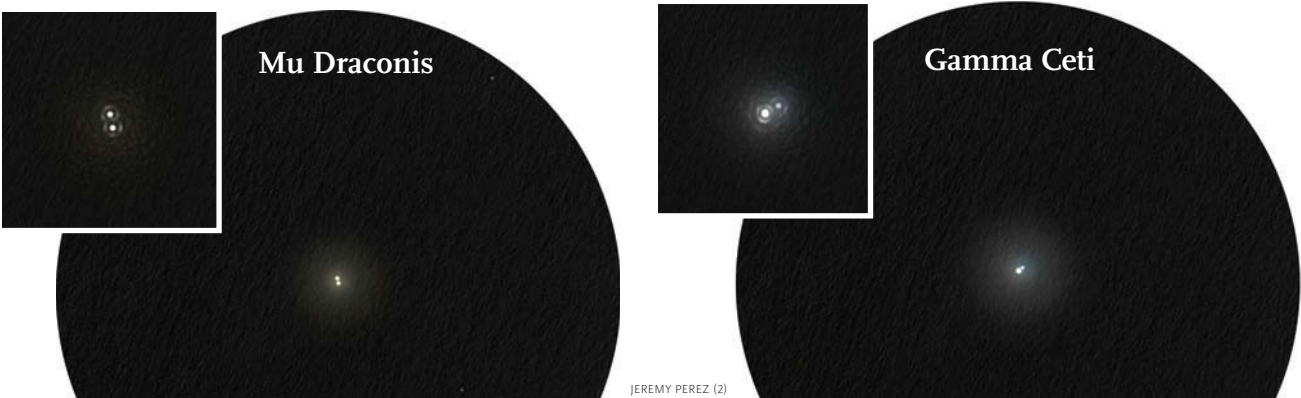
Mu Draconis and Gamma Ceti both have separations of 2.3", but Gamma is a much tougher split due to the 2.6-magnitude difference between its components.

pairs in the deep-southern sky. That's why I'm begging for volunteers to help me. If enough of you come to my aid, we should have a scope of the right size to test every position in the chart. I can always get back to you about missing observations that are within range of your scope and hemisphere.

Now let's see how to use the chart to obtain these observations. Start with the first separation above the Dawes limit for your scope, beginning with the leftmost pair, whose components have a 1.0-magnitude difference. If you can't split that pair, you're unlikely to split any of the pairs to its right, which have bigger magnitude differences. So move down to the next line and try to split a wider pair with a 1.0-magnitude difference.

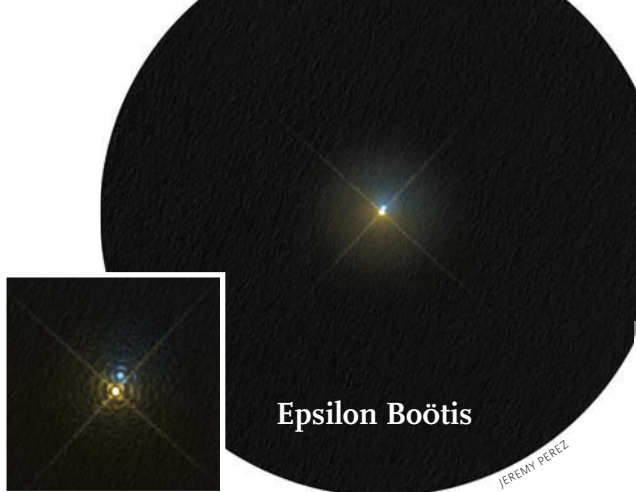
If you succeed in splitting a pair, try the one to its right, which has the same separation but a bigger magnitude difference. Keep moving to the right until you fail to split something or reach the rightmost column, at which point you should move down to the next line and start again on the left.

Let me explain with an example. Let's say that you have a 100-mm telescope. The Dawes limit for this aperture is 1.16", so you should start with the line for 1.5", the first separation on the chart that's greater than 1.16". If you live in the Southern Hemisphere, you should begin



Test Pairs by Separation and Magnitude Difference

Separation	$\Delta M = 1.0$	$\Delta M = 1.5$	$\Delta M = 2.0$	$\Delta M = 2.5$	$\Delta M = 3.0$	$\Delta M = 3.5$	$\Delta M = 4.0$
0.7"	β 332 (Pup)	ι 121 (Pav)	—	46 Vir	—	—	—
1.0"	Σ 2054 (Dra)	Hrg 47 (Car)	Σ 2403 (Dra)	41 Oph	42 Ori	—	—
1.5"	Δ 39 (Car)	—	θ Gru	Σ 2303 (Sct)	—	90 Her	γ Equ
2.0"	33 Ori	μ Cyg	49 Leo	κ Lep	3 Mon	—	—
2.5"	CapO 16 (Cir)	Σ 389 (Cam)	38 Lyn	—	H Vel	—	—
3.0"	—	—	ε Boo	ψ Cyg	23 Aql	γ Cae	ψ^2 Ori
3.5"	90 Leo	Σ 2671 (Cyg)	Σ 1181 (Vir)	See 180 (Cen)	—	h5188 (Sgr)	—
4.0"	δ Ser	65 UMa	—	Σ 2958 (Peg)	Σ 1878 (Dra)	5 Aur	Σ 3116 (CMA)



In addition to being a challenging split in small scopes, **Epsilon Boötis**, also known as **Izar** or **Pulcherrima** (meaning “most beautiful”), is famous for its contrasting colors.

with $\Delta 39$ in Carina, which has a separation of 1.5” and a 1.0-magnitude difference between its components. If you live in the U.S. you won’t be able to get a good view of $\Delta 39$, so you should start with θ Gruis, which is easy to spot from Florida and Texas, or $\Sigma 2303$ in Scutum, which is visible everywhere except the polar regions. In any case, you should move to the right until you find a pair whose magnitude difference is too big for you to split.

Then you should start on the next line, with 33 Orionis, which again is visible anywhere outside the polar regions, and move left to right through that line.

Although the logical order is top to bottom within the table and left to right within each line, you will probably end up working out of order sometimes due to seasonal considerations. There’s no point in trying to split 33 Orionis in July, when it’s hidden in the Sun’s glare! If you succeed in splitting Mu Cygni, to 33 Ori’s right, you will presumably succeed on the easier pair 33 Ori as well. But if you fail on Mu Cygni when you first read this article, remember to come back and attempt 33 Ori when it becomes visible.

With enough volunteers, we can finally put to rest the question that has dogged observers for the last century and a half. And that should be something which every participant can take pride in. This can make history! Please consider being part of this project; I can certainly use all the help I can get. Please send me e-mail at has103@comcast.net, or write to me:

Sissy Haas
823 Reamer Ave.
Greensburg, PA 15601
U.S.A. ♦

Longtime S&T contributor **Sissy Haas** is author of *Double Stars for Small Telescopes*, which is available from shopatsky.com.

Detailed Data for the Test Pairs

Const.	RA	Dec.	Name	Sep.	M ₁	M ₂	ΔM
Cam	3 ^h 30.2 ^m	+59° 22′	$\Sigma 389$	2.6”	6.4	7.9	1.5
Aur	5 ^h 00.3 ^m	+39° 24′	5 Aur	4.1”	6.0	9.5	3.5
Cae	5 ^h 04.4 ^m	−35° 29′	γ Cae	3.2”	4.7	8.2	3.5
Lep	5 ^h 13.2 ^m	−12° 56′	κ Lep	2.0”	4.4	6.8	2.4
Ori	5 ^h 26.8 ^m	+3° 06′	ψ^2 Ori	2.9”	4.6	8.6	4.0
Ori	5 ^h 31.2 ^m	+3° 18′	33 Ori	1.9”	5.7	6.7	1.0
Ori	5 ^h 35.4 ^m	−4° 50′	42 Ori	1.1”	4.6	7.5	2.9
Mon	6 ^h 01.8 ^m	−10° 36′	3 Mon	1.9”	5.0	8.0	3.0
CMa	6 ^h 21.4 ^m	−11° 46′	$\Sigma 3116$	3.9”	5.6	9.7	4.1
Car	7 ^h 03.3 ^m	−59° 11′	$\Delta 39$	1.4”	5.8	6.8	1.0
Car	10 ^h 03.6 ^m	−61° 53′	Hrg 47	1.2”	6.3	7.9	1.6
Pup	7 ^h 27.9 ^m	−11° 33′	$\beta 332$	0.7”	6.2	7.3	1.1
Vel	8 ^h 56.3 ^m	−52° 43′	H Vel	2.6”	4.7	7.7	3.0
Lyn	9 ^h 18.8 ^m	+36° 48′	38 Lyn	2.6”	3.9	6.1	2.2
Leo	10 ^h 35.0 ^m	+8° 39′	49 Leo	2.1”	5.8	7.9	2.1
Leo	11 ^h 34.7 ^m	+16° 48′	90 Leo	3.5”	6.3	7.3	1.0
UMa	11 ^h 55.1 ^m	+46° 29′	65 UMa	3.9”	6.7	8.3	1.6
Vir	13 ^h 00.6 ^m	−3° 22′	46 Vir	0.7”	6.2	8.8	2.6
Vir	14 ^h 47.1 ^m	+0° 58′	$\Sigma 1881$	3.5”	6.7	8.8	2.1
Cen	13 ^h 31.4 ^m	−42° 28′	See 180	3.6”	6.7	9.2	2.5
Dra	14 ^h 42.1 ^m	+61° 16′	$\Sigma 1878$	4.1”	6.3	9.2	2.9
Dra	16 ^h 23.8 ^m	+61° 42′	$\Sigma 2054$	1.0”	6.1	7.1	1.0
Dra	18 ^h 44.3 ^m	+61° 03′	$\Sigma 2403$	1.1”	6.3	8.3	2.0
Boo	14 ^h 45.0 ^m	+27° 04′	ϵ Boo	3.0”	2.6	4.8	2.2
Cir	15 ^h 29.5 ^m	−58° 21′	CapO 16	2.4”	7.0	8.0	1.0
Ser	15 ^h 34.8 ^m	+10° 32′	δ Ser	4.0”	4.2	5.2	1.0
Oph	17 ^h 16.6 ^m	−0° 27′	41 Oph	1.0”	4.9	7.5	2.6
Her	17 ^h 53.3 ^m	+40° 00′	90 Her	1.6”	5.3	8.8	3.5
Sct	18 ^h 20.1 ^m	−7° 59′	$\Sigma 2303$	1.6”	6.6	9.2	2.6
Aql	19 ^h 18.5 ^m	+1° 05′	23 Aql	3.2”	5.3	8.3	3.0
Pav	19 ^h 50.7 ^m	−59° 12′	I121	0.8”	5.6	7.2	1.6
Cyg	19 ^h 55.6 ^m	+52° 26′	ψ Cyg	3.0”	5.0	7.5	2.5
Cyg	20 ^h 18.4 ^m	+55° 24′	$\Sigma 2671$	3.6”	6.0	7.5	1.5
Cyg	21 ^h 44.1 ^m	+28° 45′	μ Cyg	1.9”	4.7	6.2	1.5
Sgr	20 ^h 20.5 ^m	−29° 12′	h5188	3.6”	6.7	10.1	3.4
Equ	21 ^h 10.3 ^m	+10° 08′	γ Equ	1.5”	4.7	8.7	4.0
Peg	22 ^h 56.9 ^m	+11° 51′	$\Sigma 2958$	3.9”	6.6	9.1	2.5
Gru	23 ^h 06.9 ^m	−43° 31′	θ Gru	1.5”	4.5	6.6	2.1

Easy Reflector Collimation

Achieving precise optical alignment is neither difficult nor time consuming — provided you stay on course.



Gary Seronik

I've been building and using telescopes for more than three decades, and I know from experience that collimating a Newtonian reflector is easy. So why are many people intimidated by the thought of adjusting the optics in their telescopes? One reason may be that they've done too much homework, searching online and reading everything they've found. And now they're lost in a forest of information — some of it densely technical, and, in some cases, even contradictory. This is one instance when less really can be more.

I see a lot of collimation guides that are heavily loaded with confusing details. They aren't written for the begin-

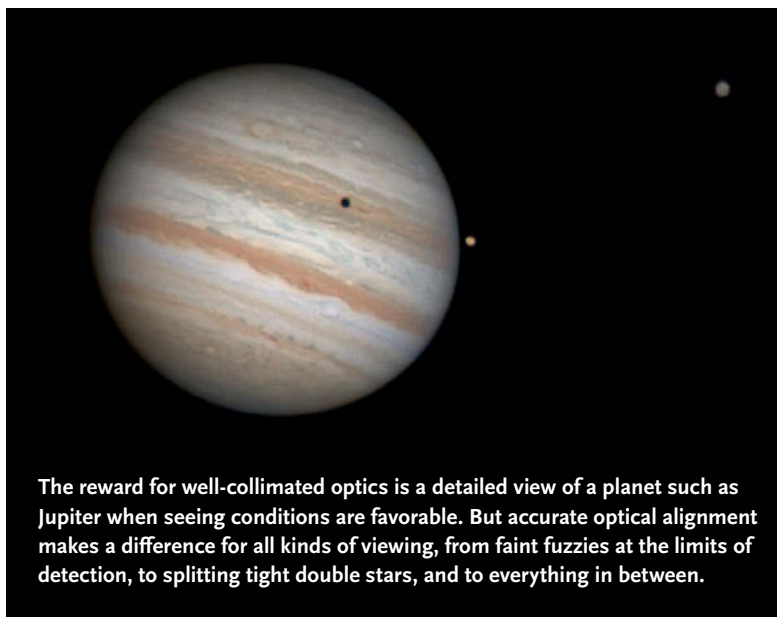
ner, but rather for people like me — hardcore telescope nuts interested in the minutiae of how their instruments work. How do you spot collimation advice that is overly complicated? Here's one fool-proof way. If the first step says to "square the focuser," then a beginner is in for a rough ride.

Collimation is a lot like routine car maintenance. Everyone needs to do it now and then to keep a car running properly, but some people will happily spend an entire Sunday afternoon under the hood of their car because they just like to tinker. If you're a telescope nut, collimation can be a form of tinkering. But the thing to remember is that it doesn't have to be. If you've recently acquired a reflector and are confused by the collimation process, then read on.

Getting Started

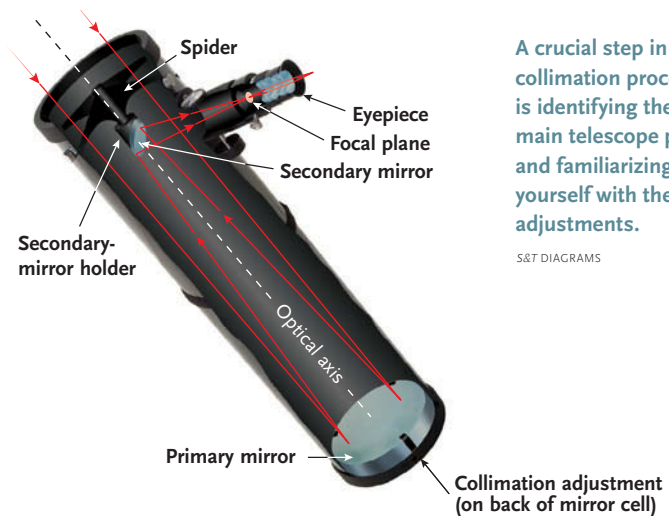
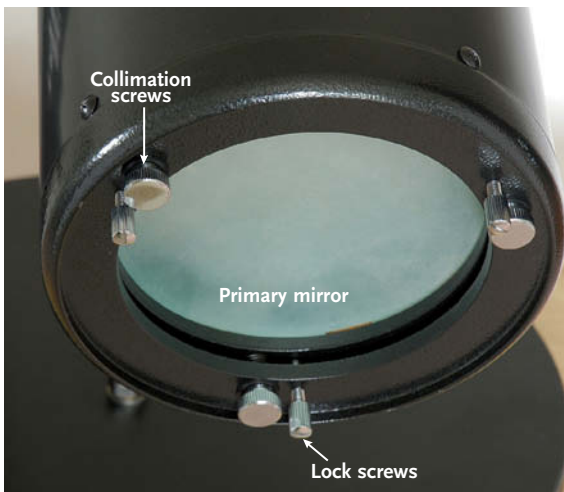
Despite a Newtonian reflector's apparent complexity, it has only three optical parts: the main mirror (called the primary), a small, flat mirror near the top of the tube (known as the diagonal, or secondary mirror), and the magnifying eyepiece. So what are we trying to do when we collimate a Newtonian? Just this: ensure that the eyepiece is aimed at the center of the primary mirror, and that the primary is aimed at the center of the eyepiece. That's all there is to it. And once you're familiar with the process of adjusting a scope's collimation, it rarely takes more than a minute or two to touch up the optical alignment. Indeed, on many nights you'll only have to confirm that everything's still okay since the last time you collimated the scope.

The first thing you need is the right tool for the job. You can check out the article "Collimation Tools: What



The reward for well-collimated optics is a detailed view of a planet such as Jupiter when seeing conditions are favorable. But accurate optical alignment makes a difference for all kinds of viewing, from faint fuzzies at the limits of detection, to splitting tight double stars, and to everything in between.

SOFT SEAN WALKER



A crucial step in the collimation process is identifying the main telescope parts and familiarizing yourself with their adjustments.

S&T DIAGRAMS

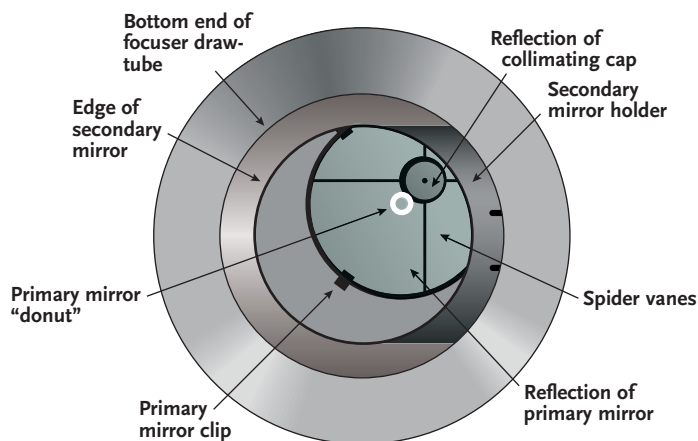
You Need & What You Don't") on my website (www.garyseronik.com) for a detailed discussion, but the bottom line is that you really can get by with just a simple collimation cap. And if your scope didn't include one, you can buy a collimation cap from vendors such as Rigel Systems (www.rigelsys.com) for about \$5.

The second preliminary task is to ensure that the center of your telescope's primary mirror is marked. Many of today's commercial Newtonian reflectors have a small paper donut at the center of the primary. If yours doesn't,

you need to mark the center (my website has instructions for doing this).

Collimation is a three-step process — #1 is to roughly align the primary mirror; #2 is to position the secondary mirror; and #3 is to fine-tune the alignment of the primary. Once the scope is collimated, on most subsequent nights you'll only need to perform step #3, if anything. It's definitely best to run through the procedure a few times in daylight — everything's a little trickier in the dark until you've gained experience.

Step #1: Initial collimation.

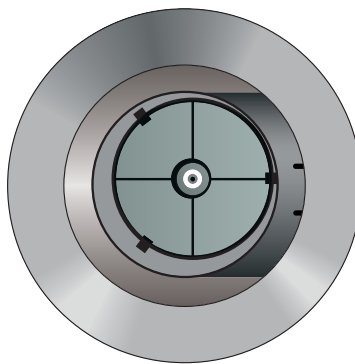


STEP #1: For the sake of clarity, both the primary and secondary mirrors are shown far out of alignment in this diagram. But this is what you'll see looking into your reflector's focuser with a collimation cap inserted. Once you're familiar with the view, aligning the parts becomes straightforward.

A collimation cap is nothing more than a small plastic piece that slips into your telescope's focuser in place of an eyepiece. It has a small peep hole drilled in its center, and the inside is usually painted white to improve its visibility among the reflected images. Start the collimation process by putting the cap into the focuser and, looking through the hole in the cap, try identifying the parts shown in the illustration above. You should pay special attention to the paper donut on the primary mirror and the reflection of the little hole in the collimation cap that you're looking through, which appears as a small black dot somewhere on the primary's surface. The goal is to adjust the tilt of the primary mirror (by turning the collimation knobs on the mirror's cell at the rear of the scope) until that black dot is centered in the paper donut.

On big scopes, it helps to have a friend make the adjustments while you look. Another tip is that you should be able to center that dot by turning just two of the three collimation knobs (it simplifies things if you're only dealing with two adjustments). I also find it easy to use the trial-and-error approach. Turn a knob. Does it move the dot closer to the center of the donut? If yes, do that some more. If no, turn the knob the other way, or try a different one. Go slowly and methodically and you should be able to center the dot in a minute or two.

Step #2: Aligning the secondary mirror.



STEP #2: When the primary mirror is correctly adjusted, the black dot of the collimation cap appears centered in the paper donut on the primary mirror.

As mentioned earlier, step #1 might be all you need to achieve accurate collimation. But you should still check that your telescope's secondary mirror is correctly positioned to ensure that the secondary is feeding 100% of the primary mirror's light to the eyepiece.

Look in the collimation cap again, and this time pay attention to the outer circumference of the primary mirror and the outside edge of the secondary mirror. To make the edge of the secondary easier to see, I tape a piece of white paper to the inside of the telescope tube opposite the focuser.

Does the primary mirror appear centered in the secondary? That is, can you see equal amounts of blackness all the way around the outside edge of the main mirror? It might be fine — I've seen a lot of scopes arrive from the factory with the diagonal mirror correctly positioned.

Most secondary mirror holders have a dizzying array of adjustments, and that's why aligning the mirror can be so intimidating. But there are really only three motions to work with. You can move the secondary back and forth, along the length of the tube. You can rotate it with respect to the focuser. And you can change its tilt. To some extent these motions are interrelated, but so long as you concentrate on dealing with one at a time, you'll be fine.

The first thing to do is get the back-and-forth distance correct. Use a ruler to measure the distance from the top of the tube to the center of the focuser. The distance from the top of the tube to the center of the secondary mir-

ror should be the same. The design of secondary-mirror holders varies, but usually loosening a big central nut or screw on the spider allows you to make the back-and-forth adjustment. And don't worry about getting the position exact — within a couple of millimeters is fine. Also, if you don't feel up to messing with this adjustment, leave it alone since chances are it was correct to begin with.

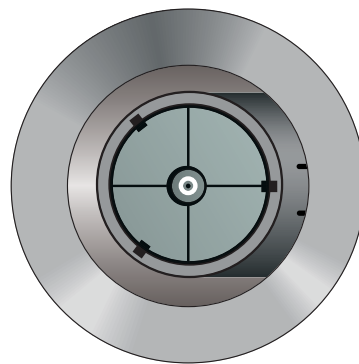
Next, you'll want to check the rotation of the diagonal. Simply eyeball this by looking down the front of the scope — you want the face of the secondary aimed at the focuser. Slightly loosening and retightening the central nut is the usual way to adjust the mirror's rotation.

Last, adjust the tilt of the diagonal until the outer edge of the primary appears concentric with the outer edge of the secondary when you're looking through the collimation cap. This often involves a small Allen key (hex wrench). As with the primary, if your secondary-mirror holder has three adjustments (and most of them do), try working with only two. Start with the focuser racked all the way in, and as you get close to good alignment, rack out until you see the outer edge of the primary appear to just about touch the edge of the secondary.

It's important to remember that even though adjusting the secondary can be the most involved part of the process, it's also the least important. So long as you can see the whole primary reflected in the secondary, you'll be fine. Getting the primary perfectly centered up is, to some extent, just gravy. And you likely won't have to mess with this adjustment very often. I've gone years without having to touch the secondary mirror in some of my telescopes. It's just a flat piece of glass with no optical power — all it does is divert light from the primary mirror out the side of the tube. A slight misalignment isn't going to ruin the views.

Step #3: Final adjustments.

If you had to do a lot of fiddling with the secondary mirror, chances are you'll need to tweak the primary, though just a little. Use the same procedure as in Step #1. But here's a little tip: if your black dot is just a tiny bit off from appearing in the center of the donut on the primary mirror, you can make your final tweak by only adjusting the secondary-mirror tilt screws, which on most scopes you can more easily access while you're looking through the collimation cap in the focuser.



STEP #3: The final major step in aligning the secondary mirror is to adjust its position so that the outer edge of the primary mirror appears centered in the secondary mirror.

Once you've completed step #3, you're done with the collimation process. Go out and enjoy using your telescope assured that it's going to deliver the very best views it can. ♦

Contributing editor **Gary Seronik** has been building and collimating scopes for more than three decades. He authors this magazine's *Telescope Workshop* column and can be contacted through his website: www.garyseronik.com.

A Brief Collimation FAQ

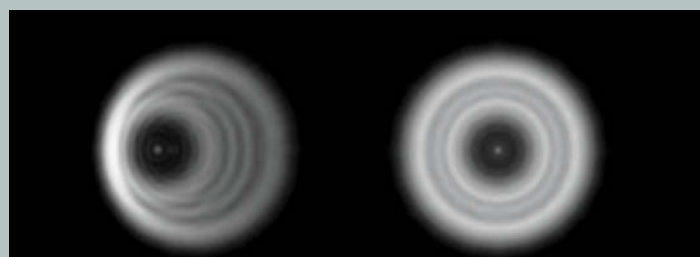
Why is collimation necessary?

A telescope's mirror produces its sharpest images only at the center of its focal plane. So you want to be sure that's the part of the image you're magnifying with your eyepiece. If, instead, due to

poor collimation, your eyepiece is aimed away from the center, the image will be blurred by an optical aberration called coma. The real-world consequence is that you'll see less detail — Jupiter's subtle belts may vanish, small

lunar craters will be hard to discern, double stars will blur into single points of light. Bad things. This is why you should collimate your scope — you want to ensure you're viewing the very best part of the primary's focal plane.

tion — its positioning only affects the uniformity of the illumination of the focal plane. That sounds serious, but if you've followed the procedure outlined in the accompanying article, you won't have to worry about it.



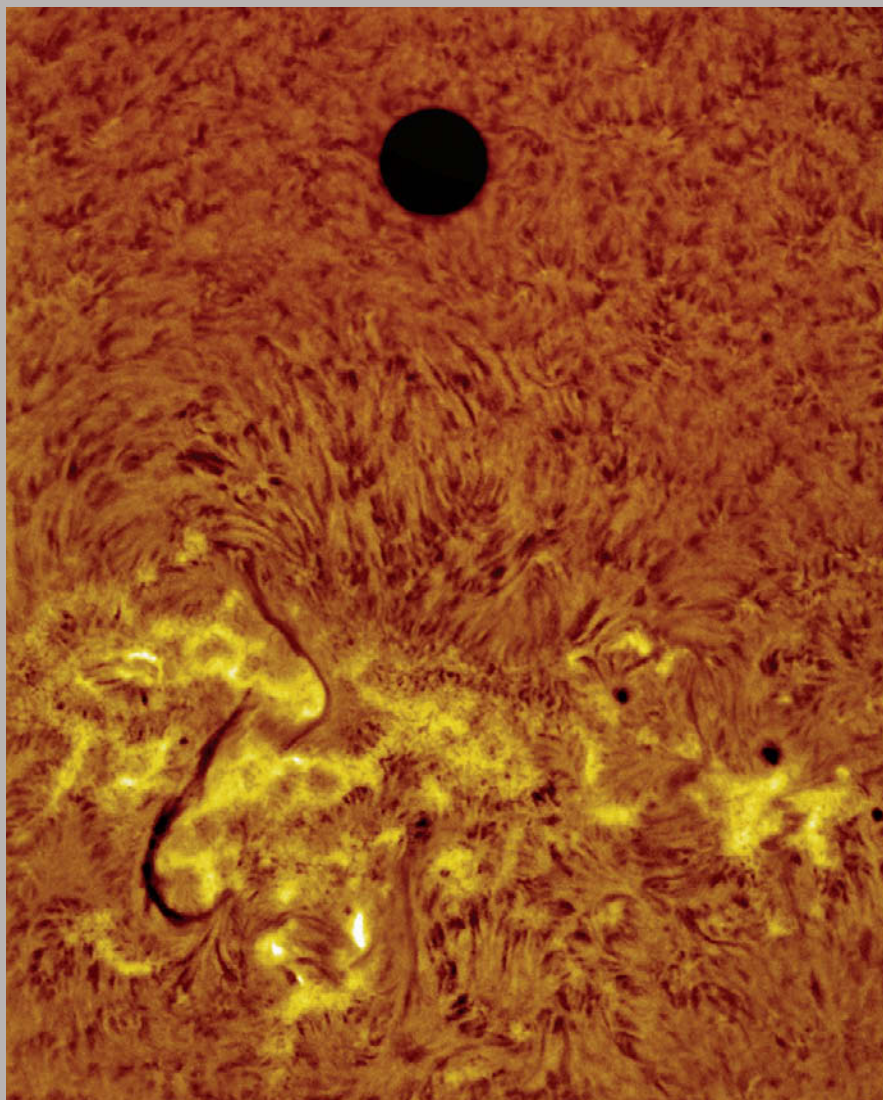
Miscollimation is obvious in out-of-focus star images seen at the center of the eyepiece field. The telescope producing the image at left is out of adjustment, while a concentric defocused star image at right indicates good alignment.

What about the secondary offset?

This is one of those collimation side roads that we telescope nuts love to head down. But for everyone else, if you've adjusted the secondary mirror so that the outer edge of the primary is concentric with it, then you've done as much offsetting as you need to. In fact, strictly speaking, the secondary doesn't really influence collima-

What about laser collimators?

I don't recommend them for beginners. Once you've mastered collimation with a simple collimation cap, you can move up to a tool such as the Orion Collimating Telescope Eyepiece from Orion Telescopes & Binoculars. Laser collimators often add a level of confusion for people who aren't familiar with the basics.



◀ VENUS ABOVE THE STORMY SUN

Jim Lafferty

During the final transit of Venus this century, the planet appeared to drift past a churning active region on the Sun's "surface" seen in the narrow wavelength of hydrogen-alpha light.

Details: Lunt Solar Systems LS100T/H α solar telescope with an Imaging Source DMK 41AU02.AS video camera. Stack of multiple frames.

▶ VOID IN THE VIOLET SUN

Sebastian Voltmer

Venus begins exiting the solar disk at the moment of third contact in this sharp image recorded in the light of calcium.

Details: Astro-Physics 105-mm f/6 Traveler EDFS with Baader Herschel Safety Wedge and Calcium K-Line Filter, and Imaging Source DMK51AU02.AS video camera. Stack of multiple frames.



▲ TRANSITING RECEPTION

Rick Scott

Venus and an array of communication antennas drift in front of the Sun in this view over the mountains near Chandler, Arizona.

Details: Meade 2045 4-inch Schmidt-Cassegrain telescope with Thousand Oaks glass solar filter. Composite of two exposures, with and without the solar filter, combined in Adobe Photoshop.

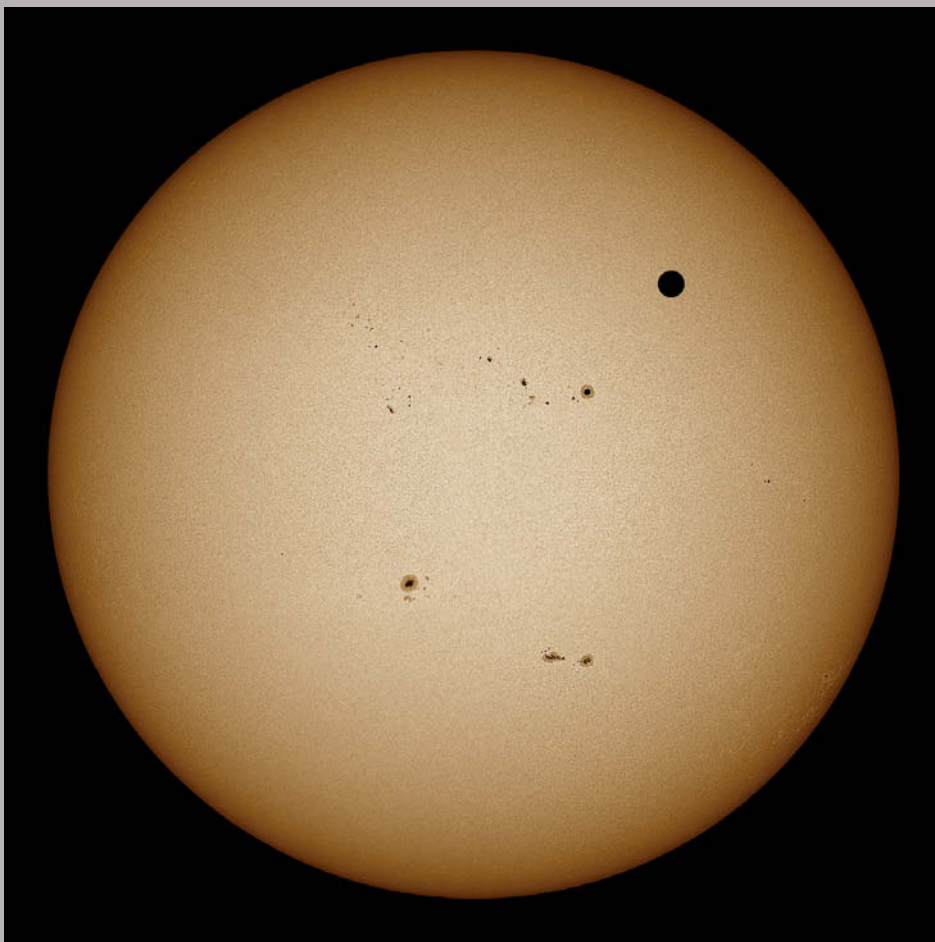
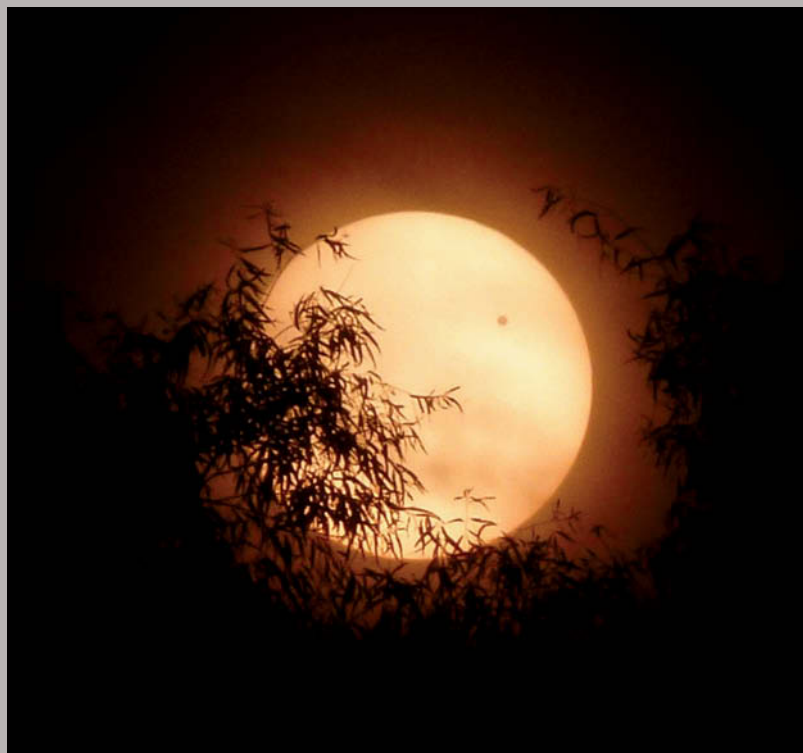
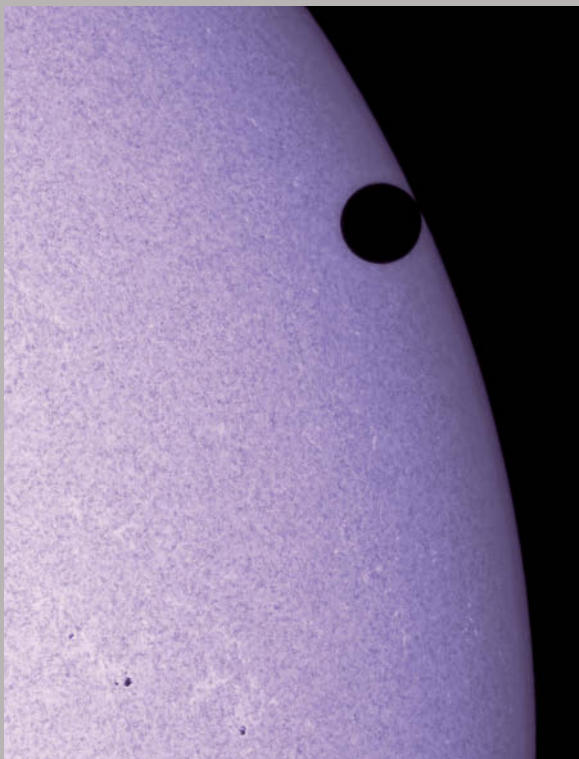


◀ SUNSET ECLIPSE

Matt Ventimiglia

This view of the May 21st annular eclipse was captured between clouds shortly before mid-eclipse from Meadow, Texas.

Details: Olympus E-30 DSLR camera with 300-mm lens. Single snapshot captured at ISO 100.



▲ STEALING A PEEK

Werner Benger

Nearby trees and evening haze in Baton Rouge, Louisiana, combined to help Werner Benger produce this beautiful photo of the silhouette of Venus on the solar disk.

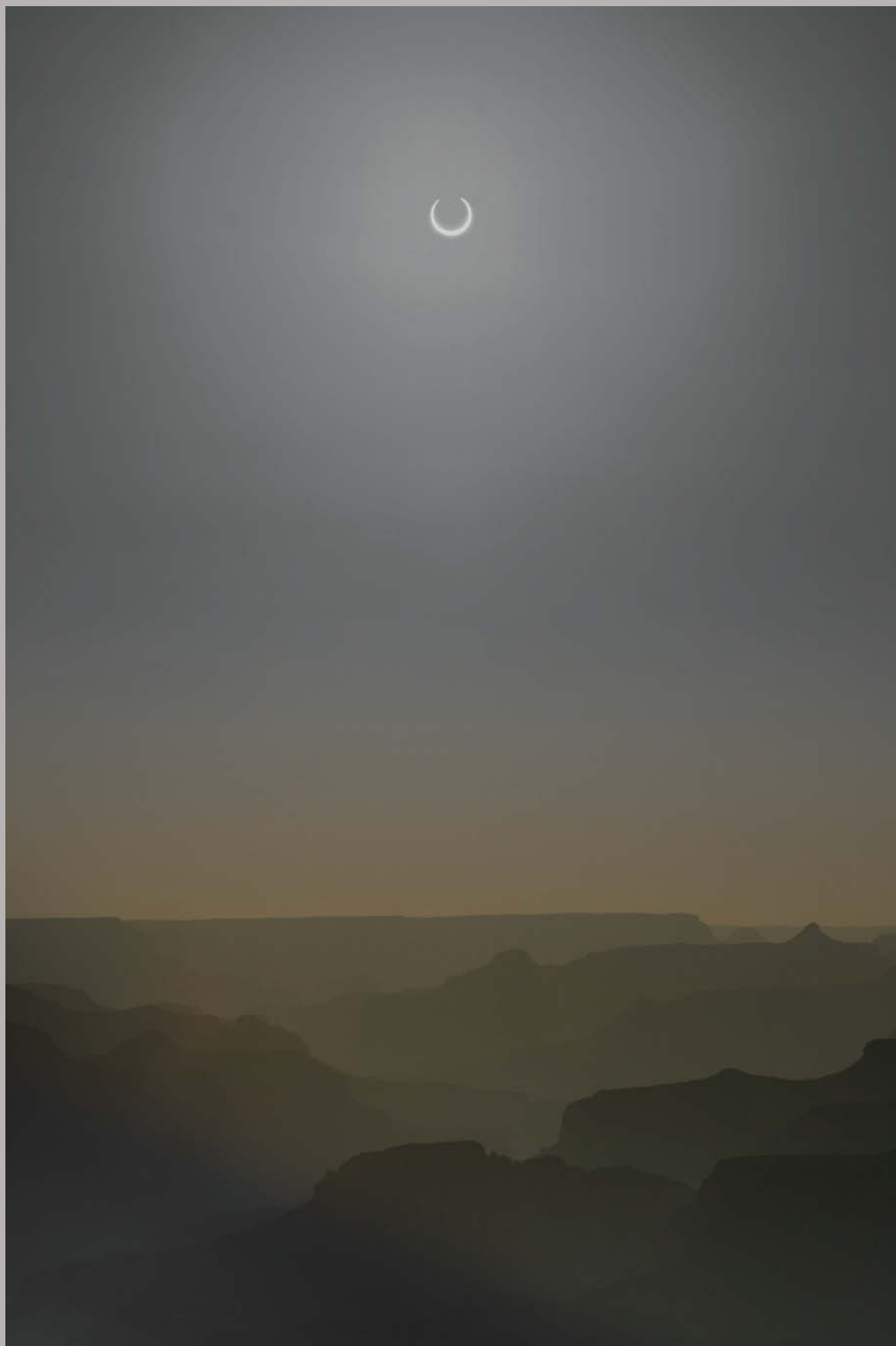
Details: *Panasonic DMC-ZS10 digital camera. Snapshot recorded at ISO 100.*

◀ SPOTS AND SILHOUETTE

Pete Lawrence

As the inky-black spot of Venus transited the Sun, it provided observers with an interesting contrast to the handful of sunspots, showing that the spots are not completely black.

Details: *Vixen FL 102-S refractor with Baader Planetarium AstroSolar Safety Film and Lumenera SKYnyx2-0 video camera. Mosaic assembled from stacked video frames.*



Gallery showcases the finest astronomical images submitted to us by our readers. Send your very best shots to gallery@SkyandTelescope.com. We pay \$50 for each published photo. See SkyandTelescope.com/aboutsky/guidelines.

CRESCENT HAZE

Michael P. Seiler
Smoke from nearby wildfires combined with the diminished light of the eclipsed Sun give this scene above the Grand Canyon an otherworldly appearance.

Details: Nikon D800 DSLR with 70-200 mm zoom lens and graduated neutral-density filter. Composite of two photos with exposures of $\frac{1}{80}$ and $\frac{1}{8,000}$ second. ♦

**Bonus Videos,
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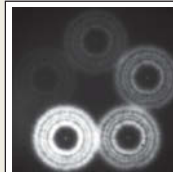
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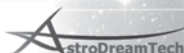
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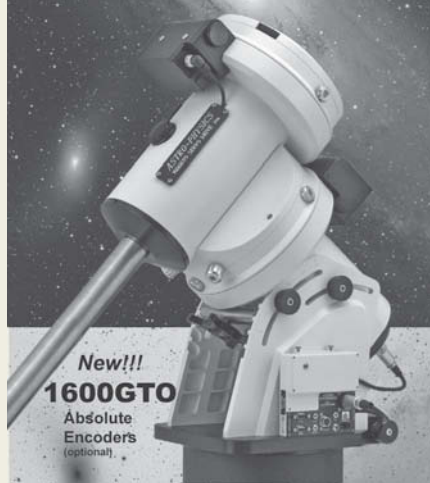
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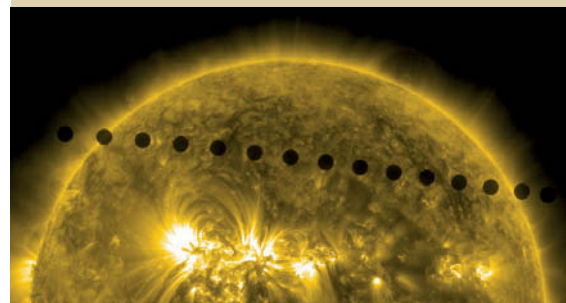
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IN THE NEXT ISSUE



Transit of Venus Highlights

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Averted Imagination

This dismissive term may discourage observers from seeing all they can see.

IN THIS INTENSELY visual hobby of ours, what gives me the most pleasure is finding faint fuzzies and occasionally seeing unexpected structure in them. I enjoy arguing with fellow amateurs about the direction of spiral arms in a nearby galaxy, or how many stars can be counted within the border of the Dumbbell Nebula (M27).

I often hear the phrase “averted imagination” at observing sessions, a play on “averted vision,” an effective observing technique of looking slightly away from a deep-sky object. “Averted imagination” is a somewhat dismissive term that bothers me. It’s certainly a clever phrase, but I think it often serves to discourage observers from seeing as much as they can see.

Like most enthusiastic observers, I have been caught “over-seeing” on a number of occasions, mostly when I try to trace out galactic or filamentary structure that really isn’t there. That doesn’t bother me much because I think it’s a great exercise to push my visual perception up to and beyond its limits. It’s gratifying to discover what those limits are, even though I occasionally have to fine-tune them back a few notches.

Disciplined sketching would show that most of us *can* see more than we think we can. But fear of being accused of “averted imagination” (always with a light-hearted chuckle) can discourage us from making a try at borderline photons. At the Oregon Star Party a few years ago, I spoke with an experienced observer who regarded the Silver Coin Galaxy (NGC 253 in Sculptor) as a challenge. He claimed normal eyesight and was using an 18-inch Dobsonian reflector. But this galaxy is an easy object even in binoculars. Perhaps he was



intimidated by all the subtle peer pressure not to over-see.

On May 5, 2012, I took a close but unaided look at the full Moon at 1:00 a.m. PDT. It was almost at the very moment of fullness, and very nearly at maximum perigee. The media was calling it the “supermoon.” To me it looked considerably brighter than I remember (though months of cloudy Oregon weather may have dimmed my memory). And yes, it really did seem larger than usual.

Like the rest of you, I roll my eyes when I hear of yet another internet iteration of the Monster Mars myth, and I’m a bit skeptical when someone else claims to see a difference between the full Moon at apogee and the full Moon at perigee. If I hadn’t known of the special occasion beforehand, would I have noticed any difference in angular diameter? Probably not; almost certainly my imagination was at work. But I don’t care; the sight was memorable and

magnificent! In this case, imagination governs; no harm comes from being wrong.

Einstein once wrote, “Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.” Consider for a moment these lines by William Blake:

*The moon, like a flower
In heaven’s high bower,
With silver delight,
Sits and smiles on the night.*

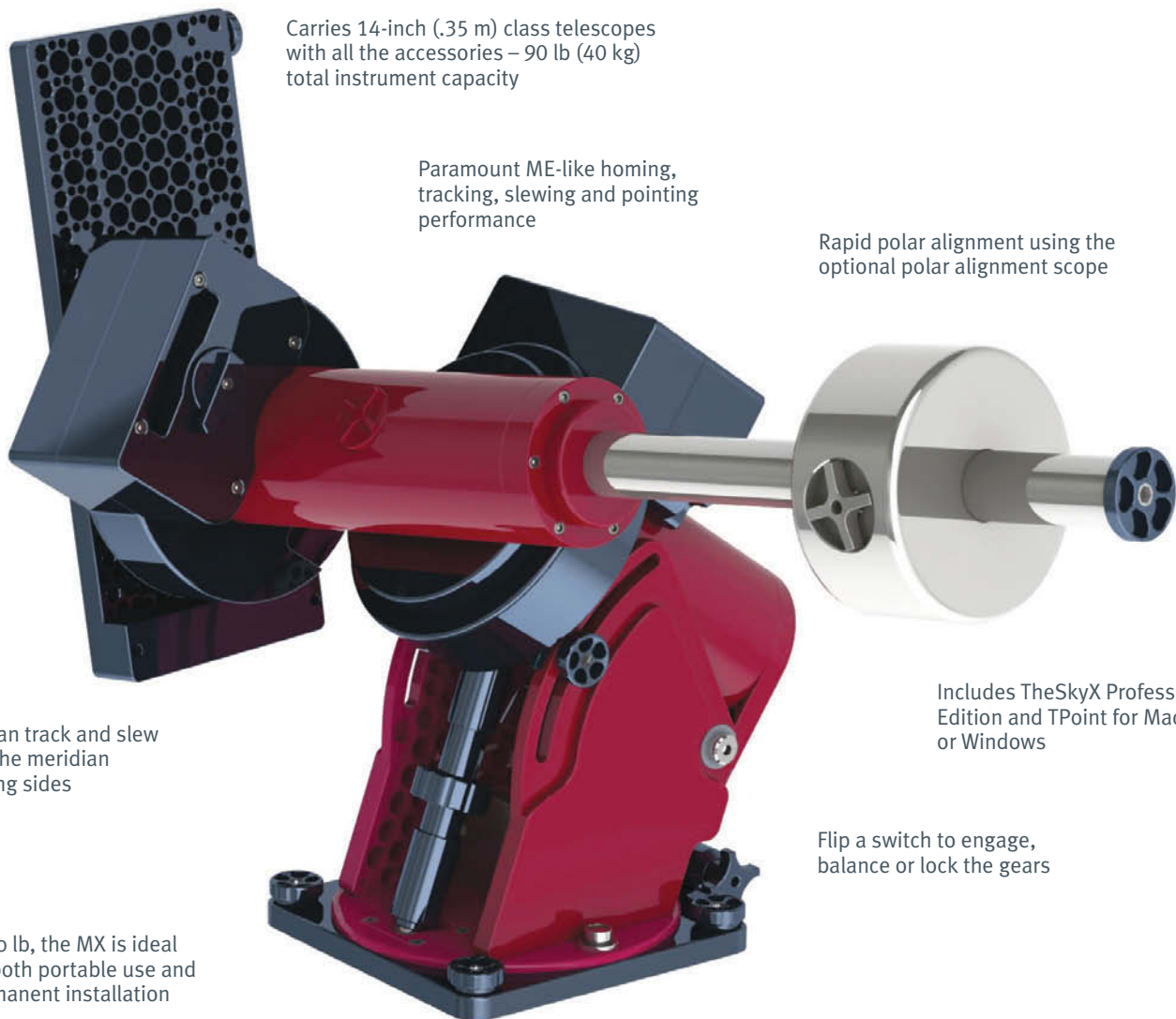
...and then recall what many of you might have heard that night:

“Oh, wow, look at the Moon!”

The difference is imagination. That’s not a bad thing, though it needs to be checked against reality now and then. ♦

Dan Rinnan has spent 55 years in his quest for faint fuzzies, most of it before the Dobsonian revolution.

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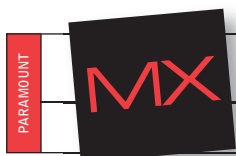
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